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An Informal Conference on Liriomyza Leafminers

FOREWORD

Liriomyza leafminers (Diptera: Agromyzidae) are economically important pests on ornamental and vegetable crops in many regions of the world. Because of the importance of current research views on *Liriomyza* leafminers, this conference was organized to help disseminate information and ideas. These reports describe some of the current leafminer research being conducted on plant physiological responses to leafminer damage, biological control tactics, chemical control tactics, interspecific competition and visual responses to sticky cards.

Dr. Sidney L. Poe (Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061) and I moderated the conference. This informal conference on *Liriomyza* leafminers was part of the National Entomological Society of America meeting held in San Antonio, Texas, December 1984. We gratefully appreciate the help and ideas of Drs. Hiram G. Larew and Ralph E. Webb of the Florist and Nursery Crops Laboratory, USDA.

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CONTENTS

Physiological Responses of Vegetables to Damage by *Liriomyza trifolii* (Diptera: Agromyzidae)

John T. Trumble[1]

Introduction

The damage potential of the polyphagous agromyzid, *Liriomyza trifolii* (Burgess), has been exhaustively documented by many researchers (Poe 1982, Spencer 1973). Even though the economic losses attributed to this leafminer have recently stimulated considerable research designed to provide information on 1) leafminer biology (Leibee 1981, Parrella 1984), 2) chemical control strategies (Schuster and Everett 1983, Webb et al. 1983), 3) resistance management (Keil and Parrella 1982), 4) ecology (Zehnder and Trumble 1984, 1984b) and 5) integrated control programs (Trumble and Toscano 1983), little effort has been made to determine the physiological responses of the host plant to leafminer infestations. A notable exception is the study by Johnson et al. (1983) on the effects of feeding by *L. sativae* Blanchard on a commercial variety of tomatoes, *Lycopersicon esculentum* (Mill.).

Until the invention of the dual isotope porometer, statistical analysis of factors influencing photosynthesis and related processes was extremely difficult and tedious. The problem was primarily due to the variability in location and photosynthetic activity of chlorophyll in plants (Boulanger 1958, Bruinsma 1963). Therefore, predicated on the availability of the porometer, the research reported here was conducted to determine the impact of adult feeding and larval mining on such basic physiological processes as photosynthesis, transpiration, stomatal conductance and mesophyll conductance. Related investigations in experimental plantings in Orange County, California, were designed to document the effects of various levels of leafminer damage on plant growth patterns and, ultimately, yield. Much of the research presented here is the result of a cooperative study with Dr. Irwin Ting and Loretta Bates of the Botany and Plant Sciences Department of UCR, and will appear in 1985 in *Entomologica Experimentalis et Applicata*.

Methods

The dual isotope porometer was used to measure rates of photosynthesis, transpiration, mesophyll conductance, and stomatal conductance for celery (*Apium graveolens* L.) plants subjected to preselected densities of leafminer damage. The specific design and operation of the porometer is available (Johnson et al. 1979) and will not be duplicated here. The

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gas exchange equations used to calculate the physiological parameters are as follows:

$$\text{Photosynthesis in mg } CO_2/\text{area/time} = \frac{CO_2}{R_s + R_m} \quad \text{and}$$

$$\text{Transpiration in g } H_2O/\text{area/time} = \frac{H_2O}{R_s}$$

where CO_2 = the difference in concentration of carbon dioxide between the atmosphere and the leaf surface,

H_2O = the difference in water concentration between the leaf and the atmosphere,

R_s = the stomatal resistance to H_2O or CO_2 exchange in cm/sec,

R_m = the resistance of the mesophyll to assimilation of CO_2 in cm/sec.

Initially, a series of twenty undamaged celery plants were evaluated with the porometer to determine how comparable photosynthesis and related parameters were between specific leaves, petioles, and plants. All celery plants were of the same variety (5270-R) and seedlot, and grown under identical conditions in the greenhouse (i.e. soil type, moisture, light, etc.). Thus, the plants were as uniform as possible. Concurrent with measurements taken with the porometer, a variety of environmental variables were monitored, including a) ambient temperature, b) leaf surface temperature, c) relative humidity, and d) incident radiation.

All comparisons of leafminer damaged and undamaged leaves were conducted on the first and second pairs of opposite leaves adjacent to the distal leaf on upright celery petioles. Since such opposite leaves were determined to be equivalent in terms of photosynthesis rates, leafminers were confined to the upper surface on one leaf of each pair of leaves using small styrofoam cages. To assess the impact of leafmining, one female and two males were confined per cage for approximately 1-4 hours, allowing oviposition to occur at a relatively low rate. Cages were then removed, and plants were returned to the greenhouse where larvae completed development and exited the leaves. Only leaves upon which a single leafminer developed were tested. Porometer samples were taken distally on the leaf, with the mined area between the petiole and the sample area. The same location was then sampled from the opposite, undamaged leaf. Porometer samples were collected from 120 leaves, providing 60 comparisons of damaged versus undamaged leaves.

In a second experiment, the physiological impact of adult feeding was evaluated by confining newly emerged, non-ovipositing females to the upper surface of one of each pair

of opposite leaves. Following approximately 12 hours of exposure, cages were removed and plants were transferred to the greenhouse. The number of feeding punctures on each leaf disk was counted after sampling with the porometer, allowing values to be readily converted to feeding punctures per cm^2.

As discussed in the results section, not all leaves, petioles and plants were comparable in terms of photosynthesis rates and related processes. Therefore, direct, quantitative comparisons of rates of each physiological variable between separate plants, or even petioles within the same plant, would not be statistically valid. However, opposite leaves in selected locations were equivalent, and proved suitable as a substrate for assessing the effects of leafminer damage. The analyses presented in Tables 1 and 2 were therefore generated using a paired t-test which evaluated whether differences between opposite damaged/undamaged leaves were significant. Thus, the results shown in these tables are given as levels of significance at which the null hypotheses (physiology of damaged leaves = physiology of undamaged leaves) can be rejected.

A variety of plant growth parameters was monitored weekly for celery plugs and transplants which were exposed to high and low levels of leafminer infestations in an experimental planting of 5270-HK celery in Orange County, California. All plants were germinated from the same seedlot and grown to transplant size with the same greenhouse operation. Populations of L. trifolii were manipulated in the field with weekly pesticide applications: methamidophos at 1.0 lg ai/acre minimized leafminer density and methomyl at 0.9 lb ai/acre maximized populations. Treatments of plugs and transplants were randomized in a complete block design with each treatment replicated 4 times. Each replicate consisted of 4 beds (2 rows/bed) X 65 ft. Data on mean numbers of mined leaves/plant, plant height, number of total leaves/plant and numbers of petioles/plant were collected for 8 weeks following the first pesticide application. Plant growth was also evaluated at harvest. All statistical analyses were generated with the Duncan's new multiple range test (DMRT).

Results and Discussion

Comparisons of rates of photosynthesis and related physiological processes between plants, petioles and leaf location determined that not all plants, petioles within plants, or leaves upon petioles are equivalent. In spite of the uniform growing conditions and appearance of the celery examined, at least three statistically separate groups of plants were identified out of the 20 tested. Upright petioles proved to be more uniform in most physiological parameters than those petioles deviating from vertical.

This effect is not surprising as petioles with an increasing horizontal aspect frequently had begun to senesce, exacerbating the variability in chlorophyll activity. Fortunately, some opposite leaves were comparable. The first and second pairs of opposite leaves adjacent to the distal leaf on vertical petioles were not significantly different in any of the physiological parameters tested for any of the 20 plants. Leaves at other locations on the petiole had either much higher or much lower levels of activity. Therefore, the first and second pairs of opposite leaves were utilized as sample substrates throughout this study.

The impact of leafmining on celery physiology is presented in Table 1. A single leafmine significantly reduced stomatal conductance, mesophyll conductance, transpiration and photosynthesis. These results are generally in agreement with those of Johnson et al. (1983), where L. sativae was shown to cause similar reductions in photosynthesis and transpiration. Clearly, a disruption of the vascular system in celery affects the movement of water which, in turn, causes changes in turgor pressure. This results in a reduction in stomatal conductance, which inhibits transpiration and, ultimately, photosynthesis.

The effects of feeding damage by adult L. trifolii on celery physiology is presented in Table 2. Feeding punctures occurring at a density of less than ca. 13/cm^2 did not affect any of the physiological parameters evaluated. However, between 13-19 punctures/cm^2, a low level, all processes were significantly reduced. Since the density of feeding/oviposition punctures frequently exceeds this level in the field, the previous view that such damage was negligible may not be valid.

Relative leafminer damage was compared between cultural and chemical treatments using the data on percentages of mined leaves per plant (Table 3). No significant differences in percent of mined leaves per plant were found for eight week averages. Unfortunately, information on percent mined leaves per plant does not provide accurate comparisons between treatments unless several other factors are considered, including leafminer larval survival and rates of parasitism. In addition, plant height, number of petioles, and number of leaves per plant should be taken into account or data on the percent of mined leaves per plant will not be biologically significant.

Leafminer larval survival was significantly reduced in methamidophos treated celery, but survival increased in plots sprayed with methomyl. Also, percent parasitism (based on leafminer and parasite emergence) was significantly greater in control and methamidophos treatments (ca. 50%) than in celery sprayed with methomyl (ca. 25%). Thus, even when the percentages of mined leaves were not different

between treatments, more mines contained dead or parasitized larvae in the methamidophos treatments than celery where methomyl was applied. A general decrease in the size of mines and a corresponding reduction in physiological damage to the test plants resulted.

The effect of leafminer feeding on plant height has been shown in Table 4. On each sampling date, plants treated with methomyl were smaller than those treated with methamidophos. Differences in height were significant (P=0.05 level, DMRT) between chemical treatments on five of the eight sampling dates. Since smaller plants have fewer leaves and less leaf area per leaf, small plants would be more seriously affected by leafminer damage at a given percent infestation than plants with greater size. A comparison of chemically treated plants with control plants (untreated) found that both damage and plant height parameters were intermediate for control plants, indicating that leafminer damage and not chemical phytotoxicity was the primary cause of variation in plant growth.

The mean numbers of leaves per plant were also significantly different (P=0.05, DMRT) between treatments (Table 5). Transplants had more leaves than plugs on every sampling date, and transplants sprayed with methamidophos had significantly more leaves than those treated with methomyl on six of the eight sampling dates. In four of the last six samples, plugs treated with methomyl had significantly fewer leaves than plugs exposed to methamidophos.

As a result of slower growth due to leafminer damage, plugs sprayed with methomyl developed significantly fewer petioles than all other treatments (Table 6). By the seventh week of sampling, plugs treated with methamidophos had as many petioles as transplants in the methomyl treatment. Only those transplants where leafminer damage was suppressed with methamidophos produced more petioles.

Acknowledgements

The assistance of H. Nakakihara, W. Carson and J. Feaster in the field is appreciated. Bud of California provided the plugs, and Mr. J. Fuji provided seeds and transplants. This research was supported in part by grants from the California Celery Research Advisory Board and the Academic Senate of the University of California, Riverside.

Table 1. Impact of leafmining by L. trifolii on selected physiological parameters of celery.

Physiological process	Units	Paired comparison analysis[a]
Stomatal conductance	cm/sec	>0.001
Mesophyll conductance	cm/sec	>0.001
Transpiration	g H_2O/area/time	>0.002
Photosynthesis	mg CO_2/area/time	>0.001

[a] n = 60 comparisons, values indicate level at which the hypothesis "physiology of damaged leaves = physiology of undamaged leaves" can be rejected.

Table 2. Relationship between density of feeding punctures of L. trifolii and celery physiological processes.

Feeding punctures per sq. cm	Paired comparison analysis[a]			
	Stomatal conductance	Mesophyll conductance	Transpiration	Photosynthesis
0 - 6.3	NS	NS	NS	NS
6.4-12.7	NS	NS	NS	NS
12.8-19.1	NS	NS	NS	0.1
19.1+	0.01	0.001	0.02	0.001

[a]NS = not significant at $P \leq 0.05$; values indicate level at which the hypothesis "physiology of damaged leaves = physiology of undamaged leaves" can be rejected.

Table 3. Interactions of cultural and chemical treatments on percentages of mined leaves per celery plant in Orange County.

Cultural technique	Weekly treatment	Rate (lb ai/acre)	$\bar{x} \pm$ SD percent mined leaves/plant[a]
Plugs	Methomyl	0.9	38.5 $\pm$ 7.2
Plugs	Methamidophos	1.0	40.9 $\pm$ 9.7
Transplants	Methomyl	0.9	50.1 $\pm$ 5.8
Transplants	Methamidophos	1.0	46.1 $\pm$ 10.3

[a] Counts from 20 plants/week/treatment for 8 weeks.

Table 4. Impact of leafminer feeding on plant height.

		Plant Height (cm)*							
		Aug	September					October	
Treatment	Cultural Technique	25	1	8	15	22	29	6	13
Methomyl	Plugs	4.0 a	4.5 a	4.5 a	5.5 a	9.0 a	13.0 a	18.5 a	22.5 a
	Transplants	14.5 b	15.5 b	15.0 b	17.5 b	22.0 b	35.0 b	39.5 c	49.0 c
Methamidophos	Plugs	3.5 a	4.0 a	6.0 a	7.5 a	12.0 a	14.0 a	22.5 b	31.0 b
	Transplants	15.0 b	13.0 b	15.5 b	21.0 b	28.5 c	38.5 b	46.0 d	53.5 d

* Means in columns followed by the same letter are not significantly different at the $P \leq 0.05$ level, DNMRT.

Table 5. Influence of leafminer density on the mean number of leaves per celery plant.

		$\bar{x}$ No. of leaves per plant							
		Aug	September					October	
Treatment	Cultural Technique	25	1	8	15	22	29	6	13*
Methomyl	Plugs	10	12	15	19	37	45	83	113 a
	Transplants	31	37	38	62	67	123	184	212 c
Methamidophos	Plugs	12	16	24	35	44	55	100	163 b
	Transplants	26	40	48	86	124	166	231	240 d

* Means in columns followed by the same letter are not significantly different at the $P \leq 0.05$ level, DNMRT.

Table 6. Mean number of petioles/plant in celery plugs and transplants with methamidophos and methomyl.

Culture and treatment	Mean no. petioles/plant[a]						
	25 AUG	8 SEP	15 SEP	22 SEP	29 SEP	6 OCT	13 OCT
Plugs methomyl	3.2 b	3.9 c	4.5 c	6.1 c	7.4 c	14.2 c	16.6 c
Plugs methamidophos	3.2 b	3.5 b	5.7 c	8.6 b	9.7 c	18.0 b	22.0 b
Transplants methomyl	4.1 a	6.6 b	9.3 b	9.2 b	15.5 b	22.1 b	22.6 b
Transplants methamidophos	4.1 a	8.2 a	12.8 a	17.0 a	23.7 a	29.4 a	28.2 a

[a] 5 plants per replicate per date; 4 replicates per treatment; means in columns followed by the same letter are not significantly different at the $P \leq 0.05$ level, DMRT.

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Parasitization of Liriomyza trifolii by Diglyphus intermedius

K. J. Patel[1] and D. J. Schuster[2]

Summary

Diglyphus intermedius (Girault) is one of 4 major parasitoids attacking Liriomyza spp. leafminers which infest fresh market tomatoes on the west coast of Florida. Despite the abundance of this parasitoid, relatively little is known regarding its basic biology. In previous studies, we found that developmental rates of D. intermedius eggs, larvae and pupae were quadratically related to temperature with highest developmental rates occurring at about 27° C. The purpose of the present investigation was to evaluate the selected factors affecting oviposition.

Fecundity, longevity and host mortality of D. intermedius were studied at 5 constant temperatures ranging from 15.6 to 31.1° C. One-day-old parasitoids were provided 20, 3rd instar L. trifolii (Burgess) larvae in excised tomato leaflets every 24 hrs. The circadian pattern of oviposition was studied by providing 5-day-old parasitoid females with 15 3rd instar L. trifolii larvae in excised tomato leaflets every 4 to 12 hours of a 12L:12D day. To study host size preference, 5-day-old parasitoid females were simultaneously provided 20, 2nd instar and 20, 3rd instar L. trifolii in excised tomato leaflets for a 4 hr period. In all experiments, dead leafminer larvae were dissected from the foliage and the presence of parasitoid eggs determined.

The fecundity of D. intermedius was related quadratically to temperature. Oviposition increased slightly as temperature increased from 15.6 to 19.4° C, but decreased sharply above 23.3° C. Large numbers of L. trifolii larvae were killed in the absence of oviposition (host feeding). The relationship of temperature to host feeding was inversely linear. This effect was apparently due to the effect of temperature on longevity which also declined linearly as temperature increased. D. intermedius oviposition and host feeding was greatest during the first 4 hours after lights were turned on. Activity was much less during the next 8 hr period, and practically ceased after lights were turned off. D. intermedius preferred 3rd instar L. trifolii larvae for oviposition and host feeding; however, 2nd instar larvae were also utilized.

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D. intermedius appears to be a very good parasitoid of *L. trifolii* when considering the combined mortality inflicted by oviposition and host feeding. However, these studies were conducted under conditions of high host abundance. Searching capacity and efficiency must be further evaluated. Under high temperature conditions, *D. intermedius* appears to be much less suitable since developmental rates, oviposition, host feeding and longevity are less at high temperatures. This may at least partially explain why *L. trifolii* populations increase dramatically in the spring in Florida.

The Interaction of Parasites and Leafminers on Commercially Grown Chrysanthemum

M. P. Parrella[1], V. P. Jones[1], and G. D. Christie[1]

Biological control of arthropods on an ornamental crop such as chrysanthemum is generally considered unfeasible due to the high aesthetic value of the crop. For this reason, the application of biological control on most ornamentals is thought to be impossible throughout much of the world (Lenteren et al. 1980). However, this is not true with chrysanthemums grown for cut flowers for several reasons. First, only the upper two-thirds of the plant is harvested with the remainder left in the bed to be tilled under. Thus, the lower plant foliage (the first 4-6 weeks of crop growth) can be damaged without affecting the marketed commodity. Second, the leafminer, Liriomyza trifolii (Burgess), has developed resistance to numerous insecticides and is very difficult to control even with repeated applications of highly toxic materials (Keil et al. 1985). Therefore, growers may be able to obtain a crop of good quality using biological control of leafminers which would be equal to that provided by the use of insecticides. This may stimlate the adaption of biological control on chrysanthemum in much the same way as the development of pesticide resistance in Tetranychus urticae Koch (Acari: Tetranychidae) in Europe after World War II revived the application of biological control on vegetables (Lenteren et al. 1980). Third, effective leafminer insecticides are available which are compatible with natural enemies (Parrella et al. 1983a, Pettit et al. 1984). Control exerted by natural enemies and the pesticide may lessen selective presssure on L. trifolii to develop resistance to the chemical, therefore, effectively increasing its useful field life. In addition, growers may be willing to adopt biological control if they recognize that any new chemical is but a temporary solution to the problem.

Biological control of the leafminer, Chromatomyia syngenesiae Hardy, on chrysanthemum has been successfully achieved in England with several species of parasites (Cross et al. 1983). This leafminer species has a much lower reproductive potential than L. trifolii (Parrella et al. 1983b, Cohen 1936), and pupates within the leaf. Consequently, the tactics employed in England may not be applica-

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ble to biological control of L. trifolii on chrysanthemum. Also, while insecticide resistance has been demonstrated for C. syngenesiae (Hussey 1969), this species is considered to be far more susceptible to pesticicides than L. trifolii (Lindquist et al. 1984).

Research on biological control of L. trifolii on chrysanthemum has been limited (Prieto and Chacon 1980, Price et al. 1981). Price et al. (1980) indicated that improved management techniques for L. trifolii on chrysanthemum are needed before the full potential of integrated pest management on this crop can be realized. Here, we report a brief summary of a study where parasites alone and parasites plus an insect growth regulator (IGR) were used in feasibility studies to evaluate control of L. trifolii on commercially grown chrysanthemum. Control obtained through inoculative releases of parasites and immigration by natural parasite fauna was compared to normal grower practices. A second objective was to evaluate the response of the parasites to an increasing L. trifolii population on chrysanthemum.

Materials and Methods

A greenhouse was chosen in Carpinteria (Santa Barbara Co.) that encompassed ca. 2.5 ha. Three greenhouse rooms (6 m wide X 30 m long), each with 3000 'Manatee Iceberg' chrysanthemum plants, were isolated from one another with fine mesh screening (40 holes/2.5 cm^2). While this did not completely exclude parasites or flies from moving between adjacent greenhouses, it did significantly curtail their movement. Each greenhouse was a separate treatment:

Greenhouse #1 - 'Parasite House' with parasite releases only, no pesticide until late in the crop
Greenhouse #2 - Trigard House with parasite releases plus cyromazine 75W at low rates (11.3 g ai/acre)
Greenhouse #3 - 'Grower House' with pesticide applications of permethrin 3.2E plus microencapsulated methyl parathion 2E two times per week at recommended rates

The schedule for releases of L. trifolii parasites and application of cyromazine is provided (Table 1). The parasite, C. parksi, was selected as the species to release early in the crop for several reasons: (1) mass-rearing is possible, (2) this species is a larval-pupal parasite and parasitized pupae can be quickly separated from those unparasitized (therefore, pupae can be directly released),

Table 1

Schedule for biological control trial, Carpinteria - 1983.

Week	Strategy
1/24	Crop planted, 3000 plants/treatment
2/18	600 L. trifolii released (all treatments)[a]
3/1	700 C. parksi released (parasite and cyromazine treatment)[a]
4/8	600 C. parksi released (parasite and cyromazine treatment)[a]
5/12	150 C. parksi released (parasite and cyromazine treatment)[a]
6/20	cyromazine applied in cyromazine treatment
7/3	cyromazine applied in cyromazine treatment
8/17	cyromazine applied in cyromazine and parasite treatment
9/24	cyromazine applied in cyromazine treatment
10/31	cyromazine applied in cyromazine and parasite treatment

[a] 50:50 female: male

(3) the fecundity is relatively high and development time short compared to other genera of leafminer parasites (Christie 1984), and (4) this species is compatible with low rates of cyromazine (Parrella et al. 1983a).

Sampling and Analysis.

All plants in each greenhouse were numbered and 16 plants/greenhouse were sampled randomly each week by removing 3 leaves from the top, middle and bottom strata of each plant. Leaves were placed in friction sealed petri dishes and returned to the laboratory where mines with live larvae were counted with the aid of transmitted light. Dead mines were also recorded. Leaves were returned to petri dishes and held for the emergence of pupae and subsequent emergence of adult flies or parasites.

Eight yellow sticky cards (7.6 cm X 12.4 cm) were spaced uniformly down the center of each greenhouse. These were held just above the plant foliage at all times during the trial. All flies and parasites caught on the traps were counted weekly and mean numbers of parasites and flies were calculated per sticky trap/week.

Means were calculated for live mines, dead mines, adult flies, and adult parasites per leaf/strata/greenhouse. Percent parasitism (adult parasites/adult flies + adult parasites) was also determined. ANOVA and Duncan's new multiple range test were used to separate means.

Results and Discussion

Throughout most of the season, all three houses had similar numbers of flies caught on yellow traps. This is a reflection of the insecticide resistance capability of *L. trifolii* at this location. Very few *C. parksi* were found on sticky traps or in leaf samples. Preliminary data suggest that the temperature in these greenhouse (which exceeded 37°C at times) was in excess of what could be tolerated by *C. parksi*. A large number of the natural parasite fauna, which were present around the greenhouse, moved into this trial in response to the leafminer populations. As expected, few parasites were trapped in the grower house, a moderate number in the Trigard house and large numbers in the parasite house. These consisted mostly of *Diglyphus* spp., and the mention of parasites from now on will refer to members of this genus. In addition, only data from the parasite house will be discussed.

Comparing the number of live mines and pupae by strata, greater numbers were found in the bottom and middle strata compared to the top. During the middle dates (weeks 6, 7 and 8), more live mines and pupae were found in the middle strata as compared to the bottom. Dates before this did not have a middle strata because plants were too short. Examining *Diglyphus* spp., the distribution of dead mines and parasites followed a similar pattern as described above, although higher numbers were not found in the middle strata compared to the bottom. This was surprising and suggests that the parasites are not responding adequately to leaf-miners in the middle of the chrysanthemum plant. Overall parasitism throughout the season was low. However, parasitism did reach high levels on specific dates (>85%).

The failure to establish *C. parksi* was attributed to excessive greenhouse temperatures but this did point out the need to augment the natural parasite fauna. In the parasite house, the crop produced was not marketable, despite high numbers of parasites and applications of cyromazine late in the crop. The need to make parasite releases early when the

infestation of leafminers is low is imperative in order to insure adequate plant quality. A further complicating factor was that at planting time, every transplant was infested with one or more live larvae of L. trifolii. This, together with releasing L. trifolii in all the treatments, produced a heavier-than-expected fly population. However, a marketable crop of chrysanthemums was produced in the parasite plus Trigard house, which demonstrates the compatibility of these two methods of control. In addition, the quality of this crop was as good as that produced in the grower house.

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Seasonal Abundance of Liriomyza Leafminers and Their Parasitoids in Fresh Market Tomatoes Grown on the West Coast of Florida

D. J. Schuster[1]

Summary

Hymenopterous parasitoid species are important in the population dynamics of Liriomyza spp. Many studies have been conducted to determine the parasitoid species attacking Liriomyza on tomato. The most abundant parasitoids vary by location and season. Data from Florida have been collected from insecticide evaluation plots. The objectives of the present study were to monitor Liriomyza and parasitoid species in insecticide sprayed and nonsprayed, fresh market, staked tomatoes.

The studies were conducted in the fall production season of 1980 and the spring production seasons of 1981, 1983 and 1984. In 1980 and 1981 0.4 ha fields of tomatoes were grown at GCREC Bradenton and were divided into 15 equal sections. Two to three weeks after planting, one plant was selected twice weekly from each of at least five sections. At each sampling, all leaflets containing occupied leafmines were held in containers in the laboratory until adults had emerged. In 1983, six commercial fields were divided such that there was at least one sampling site per ha. Each site was sampled twice weekly by examining the terminal three leaflets of the fourth leaf from the top of six branches. Leaflets containing occupied leafmines were held in the laboratory for adult emergence. Two of the six fields were similarly sampled in 1984. In 1980 and 1981 the tomatoes were not sprayed with insecticide. In 1983 and 1984, the tomatoes were sprayed according to the normal practices of each grower.

L. sativae Blanchard was the most abundant leafminer in 1980 and 1981, and peaked in the mid to late season. L. trifolii (Burgess) was more abundant in 1981 and peaked in the early season. In 1983 and 1984, L. trifolii was the most abundant leafminer. L. sativae was much less abundant and peaked in the early season. Over 95% of the hymenopterous parasitoid adults recovered were of four species. Opius sp. and Chrysonotomyia formosa (Westwood) were most abundant in 1980; Diglyphus intermedius (Girault) was most abundant in 1981; and C. formosa was most abundant in 1983 and 1984. Opius sp. and D. intermedius were of moderate abundance in 1983 and Halticoptera circulus (Walker) was of moderate abundance in 1984.

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During the course of these studies there was an apparent shift in predominant leafminer species from L. sativae (most abundant in 1980) to L. trifolii (most abundant in 1984). This apparent shift may be due to a displacement of one species by another because of competition or, perhaps more likely, because of the use of insecticides. Permethrin and methamidophos were the insecticides used early in 1984 at the time L. sativae densities decreased. The relative abundance of parasitoid species varied from one season to another. Considering proportions, Opius sp. and D. intermedius were more abundant in nonsprayed tomatoes than in sprayed tomatoes. Conversely, C. formosa was more abundant in sprayed tomatoes.

Impact of Currently Registered Insecticides on the Liriomyza/Parasite Complex in Celery, 1984.

Geoffrey W. Zehnder[1] and John T. Trumble[2]

Abstract

Six insecticides (Ambush 25W, Diazinon 50W, Dibrom 8E, Monitor 4E, Phosdrin 4E, and Thiodan 50W) were evaluated for control of Liriomyza species leafminers in celery and impact on associated parasite species. Pupal tray surveys indicated that Ambush treatments resulted in significantly higher leafminer populations and greater parasite mortality than other insecticide treatments or the control. Differential parasite survivorship occurred among treatments. A greater percentage of Chrysonotomyia punctiventris emerged from organophosphate-treated leaf samples, while Ambush treatments yielded a higher percentage of Diglyphus species parasites.

Introduction

Liriomyza trifolii (Burgess) has become an increasingly serious pest in California celery since its introduction from Florida in the late 1970's (Parrella et al. 1981). Resistance of L. trifolii to most classes of insecticides has been documented in Florida (Leibee 1981), where pesticides have been widely applied to celery for approximately 30 years. A 20-fold increase in resistance to permethrin has been reported for L. trifolii collected from greenhouses in California (Parrella and Keil 1984). The importation of resistant flies from Florida is undoubtedly a factor in the failure of most insecticides used for control of this pest in California.

In recent years, methamidophos (Monitor ®) has been one of the few insecticides proven effective in controlling leafminers in celery without suppressing parasite populations (Trumble and Toscano 1983). Unfortunately, residue levels at harvest have exceeded legal tolerances and use of methamidophos has been restricted in California. Other registered compounds have not recently been evaluated for control of leafminers and concurrent effect on associated parasite species. We, therefore, conducted field experiments to compare five compounds, currently registered for leafminer control in celery, with a standard methamidophos treatment.

Materials and Methods

Tall Utah 52-70 HK celery was transplanted August 10, 1984, at the University of California South Coast Field Station, Santa Ana, California. The crop was sprinkle-irrigated for three weeks and furrow-irrigated thereafter. Treatments were applied to single-bed replicates, 30 feet long with 3.5 feet of untreated row, or one untreated bed between replicates. Each bed contained two rows of plants 6 - 8 inches apart. Treatments were replicated four times in a randomized complete block design. Insecticides were applied weekly with a B & G CO_2 hand

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sprayer from September 14 through October 26. Two drop nozzles were utilized per bed with D3 orifice discs and #25 cores. The delivery rate was 100 gallons/acre with a wand pressure of 40 psi. All insecticide treatments included 0.04 percent spreader-sticker (Leaf Act 40).

Four plants per replicate were randomly selected and one mined (active or inactive) trifoliate from the upper and lower portion of each plant was sampled (8 trifoliate samples per replicate). Leaf samples were taken every other week from September 20 through October 18. Parasites emerging from leaves were counted and identified to species. The numbers of dead leafminer larvae in the leaves were also recorded.

Four 8 x 4 inch styrofoam pupal trays per replicate were placed between rows of plants from October 4 through November 1. Numbers of leafminer pupae and dead leafminer parasites in the trays were recorded weekly.

Results

Liriomyza pupal counts averaged for the entire season were higher in all of the insecticide plots than in the control, with significantly more pupae in the Ambush, Dibrom, and Phosdrin plots than in the control (Table 1). Fewer dead Liriomyza larvae were observed in the Ambush-treated leaves than in the control (Table 2), also suggesting that Ambush was not effective in controlling leafminer populations.

A possible factor contributing to the low efficacy of Ambush may be selective toxicity towards leafminer parasites. Greater numbers of dead leafminer parasites were observed in pupal trays under Ambush-treated plants than in other treatments or the control (Table 3). Analysis of data from leaf samples indicated that approximately 1.5 parasites per 2 trifoliates emerged from Ambush-treated leaves on September 20, 6 days after the first spray application. Parasite numbers in the Ambush plots continued to decrease thereafter, with less than 0.2 parasites per 2 trifoliates emerging from the October 18 sample.

The three most common parasite species reared from leaf samples were Diglyphus intermedius (Girault), D. begini (Ashmead), and Chrysonotomyia punctiventris (Crawford) (Table 4). In the organophosphate-treated plots (Dibrom, Diazinon, Monitor, Phosdrin) 51-60 percent of emerged parasites were C. punctiventris. In contrast, the Ambush plots yielded only 32 percent C. punctiventris and 68 percent Diglyphus species. This data suggests that C. punctiventris may have some level of tolerance to the organophosphates while Diglyphus species are susceptible to organophosphates and not affected by Ambush, a synthetic pyrethroid. In another study utilizing larger plot size, Diglyphus species proved to be tolerant and C. punctiventris was more susceptible to the organophosphate, methamidophos (Trumble and Toscano 1983). These contrary results suggest that other factors may be involved in apparent differential susceptibility between parasite species.

Additional work needs to be done to determine relative toxicity of the more frequently used insecticides towards leafminer parasites. Recent field studies have demonstrated that leafminer parasites are able to discriminate between potential habitats or leafminer host species (Zehnder and Trumble 1984). Knowledge of parasite host or habitat preference, along with information on relative toxicity of various insecticides to endemic parasites, would be useful in managing leafminer pesticide programs to conserve natural enemies.

TABLE 1. $\bar{x}$ No. *Liriomyza* pupae/tray in celery, 1984.[A]

Insecticide	Rate	10/4	10/11	10/18	10/25	11/1	Total Season
Ambush 25W	0.2 lb/acre	3.2 a	3.2 a	2.9 a	1.4 a	0.9 a	2.3 a
Dibrom 8E	1.5 pt/acre	0.8 b	1.9 b	1.9 ab	1.1 ab	1.0 a	1.4 b
Phosdrin 4E	1 pt/acre	0.5 b	1.9 b	2.0 ab	0.5 b	0.7 a	1.1 bc
Thiodan 50W	2 lb/acre	1.0 b	1.9 b	1.2 b	0.6 b	0.6 a	1.0 bcd
Diazinon 50W	0.5 lb/acre	0.4 b	1.3 b	1.3 b	0.5 b	0.7 a	0.8 cd
Monitor 4E	2 pts/acre	1.0 b	1.1 b	0.8 b	0.4 b	0.7 a	0.7 d
Control	--	0.5 b	0.7 b	0.9 b	0.6 b	0.3 a	0.6 d

[A] Means within each date followed by the same letter are not significantly different (DMRT, $P=0.05$).

TABLE 2.
$\bar{x}$ No. dead *Liriomyza* larvae per 2 celery trifoliates, 1984.[A,B]

Insecticide	Rate	$\bar{x}$ No. dead *Liriomyza* larvae
Dibrom 8EC	1.5 pts/acre	5.4 a
Phosdrin 4EC	1 pt/acre	3.3 b
Thiodan 50W	2 lbs/acre	3.0 bc
Diazinon 50W	0.5 lbs/acre	2.9 bc
Monitor 4E	2 pts/acre	2.9 bc
Ambush 25W	0.2 lbs/acre	1.7 c
Control		2.2 bc

[A] Means followed by the same letter are not significantly different (DMRT, $P=0.05$).

[B] Celery leaf samples taken every other week from 9/20 to 11/1 (data from 3 sampling dates).

TABLE 3. $\bar{x}$ No. of dead *Liriomyza* parasites/tray in celery, 1984.[A]

Insecticide	Rate	10/4	10/11	10/18	10/25	11/1	Total Season
Ambush 25W	0.2 lb/acre	2.7 a	3.3 a	2.2 a	0.2 a	1.0 a	1.9 a
Dibrom 8E	1.5 pt/acre	0.3 b	0.2 b	0.4 b	0.1 a	0.6 ab	0.3 b
Phosdrin 4E	1 pt/acre	0.2 b	0.0 b	0.1 b	0.0 a	0.4 b	0.2 b
Thiodan 50W	2 lb/acre	0.2 b	0.4 b	0.4 b	0.3 a	0.1 b	0.3 b
Diazinon 40W	0.5 lb/acre	0.1 b	0.1 b	0.1 b	0.1 a	0.2 b	0.1 b
Monitor 4E	2 pts/acre	0.3 b	0.9 b	0.4 b	0.0 a	0.3 b	0.4 b
Control	--	0.1 b	0.0 b	0.0 b	0.0 a	0.2 b	0.1 b

[A] Means within each date followed by the same letter are not significantly different (DMRT, P=0.05).

TABLE 4. PERCENT LEAFMINER PARASITES IN CELERY, 1984.[A]

INSECTICIDE	D. INTERMEDIUS	D. BEGINI	C. PUNCTIVENTRIS	TOTAL PARASITES
DIAZINON 50W	32	0	51	41
THIODAN 50W	43	14	41	56
PHOSDRIN 4E	37	5	51	76
DIBROM 8E	23	4	53	57
AMBUSH 25W	59	9	32	34
MONITOR 4E	26	4	60	27
CONTROL	35	12	43	40

[A] SIXTEEN CELERY LEAF SAMPLES TAKEN IN EACH TREATMENT EVERY OTHER WEEK FROM 9/20 TO 11/1. TWO CELERY TRIFOLIATES PER SAMPLE (DATA FROM 3 SAMPLING DATES).

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PROGRESS TOWARD DEVELOPMENT OF AN IPM PROGRAM FOR *Liriomyza trifolii* ON GREENHOUSE TOMATOES IN OHIO

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The goal of this project is to develop a practical IPM program for greenhouse tomatoes. Leafminers are major components of a pest complex that also includes whiteflies, spidermites, thrips, aphids and caterpillars. Our work with leafminers includes insecticide evaluation, selecting leafminer-resistant plants, leafminer parasite biological studies, and economic injury level evaluations. As a part of these studies, an experiment was conducted on greenhouse tomatoes during 1984. After a *L. trifolii* infestation was established on transplanted tomatoes, *Diglyphus* parasites were released. Following this, treatments consisting of parasites only, methomyl sprays every 14 days, and cryomazine sprays every 14 days were established in the greenhouses. Four plants were treated with each pesticide. We recorded leafminer and parasite adult activity during the cropping season using yellow sticky traps. Also, the number of completed, active and parasitized/dead leafmines on entire plants was recorded on several occasions. Pupae were collected in trays below plants and counted. Finally, fruit yields were recorded.

Results from yellow sticky traps indicated that adult leafminer activity peaked in week 3 (after transplanting) and week 10. *Diglyphus* adult activity peaked on weeks 12 and 18, with few or no adults trapped prior to week 10.

Significantly more pupae were collected from methomyl-treated plants than on untreated (parasites only) or cryomazine-treated plants, indicating an adverse effect of methomyl on parasites. By the end of the experiment, however, parasites had become well established on methomyl-treated plants, so this effect was temporary. Similarly, higher numbers of dead/parasitized larvae were recorded initially from cyromazine-treated plants than on methomyl-treated plants. Untreated plants (parasites only) had intermediate numbers of dead/parasitized larvae.

Fruit yields (weight only) were not significantly different among any of the treatments. We are presently evaluating the number of leafmines per leaf to determine the actual leafminer population on individual plants at various times during the crop.

Neem Seed Extract Products Control
a Serpentine Leafminer in a Commercial Greenhouse[1]

Hiram G. Larew,[2] J. J. Knodel-Montz,[2]
and Ralph E. Webb[2]

Abstract

Applied as a soil drench to bed grown chrysanthemums, 0.4% crude neem seed extract and 0.33% Margosan-O[3] (an experimental formulation of neem seed extract) caused significant pupal mortality of Liriomyza trifolii (Burgess) in an infested commercial greenhouse. Both crude neem seed extract and Margosan-O were as effective as Trigard™ in disrupting the insect's life cycle.

Summary of Experimental Design and Results

Seeds of the neem tree (Azadirachta indica A. Juss) have long been used as a source of insect repellents and insecticides (Jacobson 1981). The systemic activity of neem seed extract has been reported (Gill and Lewis 1971; Larew et al. in press). We conducted our experiment in a commercial greenhouse (Perry Hall, MD) infested with L. trifolii. We compared efficacies of crude neem seed extract and Margosan-O to that of Trigard™ (Ciba-Geigy), an insecticide known to be effective against leafminers (Price, 1984).

1/ Mention of a product does not constitute an endorsement by the USDA.

2/ Florist and Nursery Crops Laboratory, Building 470, Beltsville Agricultural Research Center, USDA/ARS, Beltsville, MD 20705

3/ Submitted for EPA registration and for patent by Vikwood, Ltd., Sheboygan, WI.

Daytime temperatures in the greenhouse ranged from 25-35°C. Weekly monitoring with 29.5 cm x 15.0 cm Sticky Strips™ (Olson Products) indicated a constant and heavy infestation of L. trifolii throughout the experiment (mean = 1805 adults/strip/wk). The greenhouse was continuously planted with chrysanthemums (i.e. there were plants of various ages in the greenhouse while we conducted the experiment). For our experiment, rooted cuttings of cv. Hartmann's Dignity were planted 10 per row in a 23 m by 1.5 m section of ground bed on March 19, 1984. The crop was grown in topsoil to which 1 bale of peat moss per 23 m^2 of bed space had been added. Plants were grown as single stem disbuds (LD from planting until April 10; SD from April 11 until bloom; disbudded May 14; bloomed June 13, 1984).

Treatment plots were 2.3 m long (15 rows/plot; 150 plants/plot) and were marked off next to each other along the bed. Plots were partitioned with plastic from the soil surface down to 15 cm below ground, and 4 rows of plants between plots were left as unsampled buffer zones. There was one plot per treatment and treatments were randomly assigned. Treatments began one week after planting and continued biweekly until 2 weeks before bloom. Sampling began two weeks after planting and continued biweekly until 1 week before bloom. Plots were both treated and sampled five times each. At sampling, four plants from each treatment were removed and the leaf area for each plant was measured. Leafminers were reared from the leaves at 24°C (18 hrs light: 6 hrs dark). Treatments included water, 0.1% and 0.4% (aqueous, w/v) crude neem seed extract made from concentrate (sample A13-42845 (AN 4.57); obtained from the Biologically Active Natural Products Laboratory, ARS, Beltsville, MD. Crude neem seed extract concentrate was made by extracting seeds in 95% EtOH, drying the extract, and then resuspending the extract in an equal weight of 95% EtOH. Crude neem seed extract concentrate contained 2300 ppm azadirachtin, one of the insecticidal principles in neem seed. Treatments also included 0.08% and 0.33% (aqueous, v/v) Margosan-O (concentrate contained 3000 ppm azadirachtin). We applied 15.6 liters of each treatment to the assigned plot as a soil drench on each treatment date. Another plot was sprayed on each treatment date with Trigard™ at a rate of 140.7 g AI/ha (0.125 lbs AI/acre). A last plot was treated by the growers ("Grower" in Table 1) when they treated the rest of the greenhouse. They sprayed irregularly with Mavrik™ (Zoecon) and Pramex™ (Penick) and applied Temik™ (Union Carbide) twice to the soil, all at recommended rates.

Mean pupal and adult counts from plants sampled at week 6 are given in Table 1. The data from week 6 are given because this was when the largest mean number of adults were reared from the water-treated plot. Only Trigard™ significantly reduced the mean number of pupae compared to the water treatment. The mean number of reared adults on week 6 was significantly lower in Trigard™, 0.4%

crude neem seed extract, and 0.33% Margosan-O plots than with any other plots. An indication of treatment effects through the season is given by the total number of pupae and adults reared from all 20 plants harvested from each plot. Trigard,™ 0.4% crude neem seed extract and 0.33% Margosan-O dramatically reduced the number of reared adults. We felt that neither 0.1% crude neem seed extract or 0.08% Margosan-O gave adequate control. No growth inhibition or other signs of phytotoxicity were observed on any of the treated plants.

Crude neem seed extract and Margosan-O did not protect the crop's foliage from damage. A 0.4% solution of neem and 0.33% solution of Margosan-O, however, greatly reduced the number of flies reared from the treated crop. Thus, insecticidal constituents of soil-applied crude neem seed extract and Margosan-O were taken up by chrysanthemums, were fed upon by leafminer larvae, and caused significant pupal death. The delay between time of application and observed effect suggests that neem acts as an insect growth regulator against L. trifolii. We are studying this possiblity.

We recommend that a commercial formulation of neem seed extract such as Margosan-O be considered further for possible use on chrysanthemums against L. trifolii.

Acknowledgements

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Table 1: Results of Commercial Greenhouse Experiment

Treatment	Mean Pupae (Wk 6)	Mean Adults (Wk 6)	Total[1] Pupae	Total[1] Adults
Water	42bc	32a	332	235
"Grower"	30c	23b	261	186
0.1% Neem	65a	14c	394	85
0.4% Neem	38bc	0.5d	189	2
0.08% Margosan-O	48ab	33a	362	225
0.33% Margosan-O	55ab	3d	350	16
Trigard TM	0d	0d	4	1

N = 4 plants/treatment. Means within a column are not significantly different at K-ratio = 100 (5% level), Waller-Duncan K-ratio t test.

[1] Total reared from all plants (20/treatment) sampled during experiment.

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Efficacy of Margosan-O, a formulation of neem, against Liriomyza trifolii (Burgess) on floral crops

Janet J. Knodel-Montz[1], Hiram G. Larew[1], and Ralph E. Webb[1]

Abstract

Efficacy of soil-applied Margosan-O, a formulation of neem, was evaluated against Liriomyza trifolii (Burgess) on four floral crops: chrysanthemum, marigold, zinnia, and snapdragon. Leafminer control varied depending on the floral crop treated. Concentrations of 0.17% and 0.33% Margosan-O were efficacious in killing larvae and pupae reared from chrysanthemums. The highest concentration of Margosan-O (0.33%) also caused a significant decline in the number of adults reared from marigolds. Reductions in the number of adults reared from zinnias were not significant from control. Too few adults emerged from snapdragons to make efficacy determinations. Leafminers preferred chrysanthemums, marigolds, and zinnias for stippling and oviposition over snapdragons.

Introduction

The botantical insecticide, neem, comes from a tropical tree (Azadirachta indica A. Juss) grown primarily in the arid regions of Asia and Africa (Radwanski 1977). The insecticidal property of neem has been known for over 20 years It is believed to act as an insect feeding inhibitor and/or growth regulator (Warthen 1979). Warthen (1979) compiled a list of seven insect orders that are affected by neem's insecticidal activity. Because neem appears to be a potent natural insecticide and may offer an environmentally safe method of insect control, a neem product called Margosan-O[2] has been developed in the United States for commercial use on ornamentals.

Crude neem seed extracts applied as foliar sprays, soil drenches and leaf dips have been found to be effective in controlling the serious leafmining pest, Liriomyza trifolii (Burgess) (Diptera: Agromyzidae) (Fagoonee and Toory 1984;

1. Florist and Nursery Crops Laboratory, BARC-East, B-470, USDA, ARS, Beltsville, MD. 20705.

2. Submitted for EPA registration and for patent by Vikwood Ltd., Box 554, 1221A Superior Avenue, Sheboygan, WI. 53081. Mention of a product does not constitute an endorsement by the USDA.

Larew et al. 1984, in press; Webb et al. 1983, 1984). *Liriomyza trifolii* is a polyphagous insect attacking a large array of floral crops (Poe 1984). In 1981, this leafminer is estimated to have caused $17 million in damages to the chrysanthemum industry of California alone (Parrella and Jones 1984). The systemic uptake of crude neem extracts has been demonstrated in chrysanthemums and several agricultural crops (Gill and Lewis 1971; Larew et al. 1984, in press; Webb et al. 1984). Since our preliminary studies have shown Margosan-O to be taken up systemically (Knodel-Montz et al. in preparation), we investigated whether soil-applied Margosan-O affected the survival of *L. trifolii* on four floral crops.

Materials and Methods

Leafminer colony

Chrysanthemums cv. Iceberg were used to rear *L. trifolii*. Chrysanthemums were grown singly in 10 cm plastic square pots in a mixture of 50% Luna Rock™ (Pennsylvania Perlite Corp., LeHigh Valley, PA) and 50% Promix™ (Premier Brand, Inc., New Rochelle, NY). Plants were left unpinched and fertilized weekly with 20N:20P:20K. Chrysanthemums were grown in a greenhouse at 23-30°C until exposure to leafminers. The leafminer colony was maintained at 24°C, with a long day photoperiod (16L:8D) at 5600 lux (high pressure sodium lamps and incandescent bulbs).

Margosan-O

Margosan-O contains 3,000 ppm azadirachtin, one of the active insecticidal components in neem (Warthen 1979). Dilutions of Margosan-O were prepared with water as volume/volume solutions.

Chrysanthemum experiment

This experiment was conducted from 29 March to 11 May, 1984. Chrysanthemums cv. Iceberg were treated with concentrations of 0.0083%, 0.083%, 0.17%, and 0.33% Margosan-O and water as control. Each treatment contained five, 3-week old chrysanthemums grown from cuttings. Each plant (pot) was drenched with 150 ml of its treatment solutions resulting in slight drainage. Plants were returned to the greenhouse for 3 days to allow for chemical uptake. Plants were then placed randomly in the leafminer colony cage and exposed to 75-100 leafminer adults for 24 hrs. After exposure, plants were returned to the greenhouse and the number of first instar mines (less than 1 cm in length) were counted (usually three to four days later). When larvae matured (third instar), damaged

leaves longer than 2.5 cm (petiole and midvein) were removed, passed through an area meter (Li-Cor, Inc., Lincoln, NE), and placed in plastic meat trays. Trays were examined daily for crawling prepupae. Prepupae were collected in gauzed-covered glass vials. Vials were kept in an environmental chamber at 26°C, 14L:10D photoperiod until adult eclosion. The numbers of pupae and adults were counted. Densities of mines, pupae, and adults were calculated on 100 cm^2 leaf area and comparisons between treatment plants and different floral crops were made.

Marigold, zinnia, and snapdragon experiments

All three floral crops were purchased from a local nursery (Beltsville, MD). The following cultivars were selected: marigold cv. Honeycomb; zinnia cv. Thumbelina Mix; and snapdragon cv. Yellow Rocket. Plants were transplanted into 10 cm square plastic pots using the same potting medium as chrysanthemums. Treatment concentrations and experimental procedures were identical to those described in the chrysanthemum experiment. However, a sample size of four plants per treatment was used, and the number of stipples (in addition to mines, pupae, and adults) was counted. Time periods were 8 June to 27 July for the marigold experiment; 18 June to 6 August for the zinnia experiment, and 14 June to 6 July for the snapdragon experiment.

Statistical Analysis

Means of first instar mines, pupae, adults, and stipples were analyzed by analysis of variance (ANOVA) and separated by the Waller-Duncan K-ratio t-test at the K-ratio = 100 (5% level). Means for the host plant preference study were analyzed using ANOVA and Duncan's Multiple Range test ($P = 0.05$).

Results and Discussion

First instar mines

In Table 1, the mean number of first instar mines and mine densities are shown for various concentrations of Margosan-O on all four crops. There were no significant differences caused by the various concentrations of Margosan-O for any of the crops. However, the number of mines and mine densities decreased on chrysanthemums at the higher concentrations. Other studies have shown no deterrance of early larval development when crude neem seed extract was applied to the soil (Larew et al. 1984, in press; Webb et al. 1984).

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The mean number of pupae and pupal densities for ɜanthemums, marigolds, zinnias, and snapdragons at the various ɘntrations of Margosan-O are illustrated in Table 2. For ɜanthemums, concentrations of 0.17% and 0.33% Margosan-O ιficantly reduced the number of pupae and pupal densities ɪred to water-treated chrysanthemums. Marigolds, zinnias, and ɪragons had no significant differences in any treatments, ɔugh the higher concentrations seemed to increase larval ɪlity. Margosan-O effectively reduced the mean number of larvae ιving to pupation on chrysanthemums, but not on marigolds, ιas, or snapdragons. This variability indicates that Margosan-O ɘred for these floral crops.

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The mean number of adults and adult densities for various ɘntrations of Margosan-O against L. trifolii on floral crops are ɿ in Table 3. A concentration of 0.083%, 0.17%, and 0.33% ɔsan-O significantly reduced the mean number of adults reared chrysanthemums. All tested concentrations of Margosan-O ificantly decreased the mean adult densities on chrysanthemums. narigolds, the highest concentration of Margosan-O significantly eased the mean number of adults and adult densities. No ificant differences were observed for any concentrations on ias and snapdragons, although a 0.33% concentration on zinnias lower mean adult counts and densities. Again, Margosan-O seemed ffect leafminer development differently depending on the floral . Margosan-O was effective in decreasing the number of adult miners reared from chrysanthemums and marigolds.

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The number of stipples was not counted for chrysanthemums. number of stipples and stipple densities for marigolds, ias, and snapdragons are given in Table 4. No significant erences in the number of stipples and stipple densities were rved for zinnias and snapdragons. For marigolds, a entration of 0.17% Margosan-O resulted in a higher stipple count a concentration of 0.0083% Margosan-O, and a higher stipple ity than 0.083% Margosan-O and water. On all three bedding s, Margosan-O did not decrease the stippling (feeding and ositional) activity of female leafminers. Larew et al. (1984, in s) and Stein (1984) also observed that soil-applied crude neem extract did not repel females from feeding or ovipositing.

Host Plant Preference

Comparisons of counts and densities of mines, pupae, adults and stipples for water-treated floral crops are shown in Table 5. Snapdragons had significantly lower counts and densities for all variables compared to chrysanthemums and marigolds. Snapdragons had significantly lower counts and densities from zinnias for the following variables: mean number of mines, pupae, adults and stipples, and mean pupal and adult densities. This suggests that snapdragons were the least preferred host plant compared to chrysanthemums, marigolds, and zinnias. Since stippling was initially lower on snapdragons, the nonpreference probably caused an effect on the later counts (mines, pupae, adults). Observations of other cultivars of snapdragons have shown that certain cultivars are heavily attacked by leafminers suggesting that the nonpreference observed for snapdragons was a factor of cultivar selection by leafminers.

Chrysanthemums, marigolds and zinnias were not significantly different in regards to either counts on densities of pupae and adults. This indicates that all three crops were equally good hosts for leafminer development. Interestingly, significantly more stippling on marigolds than zinnias did not yield significantly more mines, pupae or adults. This suggests that female leafminers preferred to feed on marigolds compared to zinnias, but showed no preference for egg laying. Further host plant preference studies need to be conducted to determine feeding and oviposition preferences of host plants by leafminers.

Conclusion

In conclusion, the efficacy of Margosan-O is variable depending on the floral crop treated. For example, a concentration of 0.33% Margosan-O was effective in killing leafminer pupae reared from chrysanthemums and marigolds, but not from zinnias or snapdragons. This was probably due to differential uptake of the product by the crops. When effective, Margosan-O appeared to prevent the larval and pupal stages from surviving. According to Larew et al. (1984, in press) and Webb et al. (1984), a 0.1% or higher concentration of crude neem seed extract applied to the soil of chrysanthemums resulted in significant larval and pupal mortality. Margosan-O has chemical control potential for leafminers; however, the variability of effects on different floral crops needs to be considered. Applying higher concentrations that are not phytotoxic or using different application techniques (i.e. foliar spray vs. soil drench) or varying the soil type (Webb et al. 1984) could overcome the problem of differential efficacy of Margosan-O on floral crops.

Acknowledgements

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Table 1. Mean first instar mines and mean first instar mine densities for various concentrations of Margosan-O used against *L. trifolii* (Burgess) on floral crops.

Treatments	Mean First Instar Mines				Mean First Instar Mines/100 cm^2 leaf area			
	Chrysanthemum**	Marigold*	Zinnia*	Snapdragon*	Chrysanthemum**	Marigold*	Zinnia*	Snapdragon*
Control	210a	126a	106a	12a	36.7a	33.0a	24.0a	10.7a
0.0083% Margosan-O	183a	149a	96a	11a	35.0a	34.7a	25.6a	16.7a
0.083% Margosan-O	160a	176a	78a	24a	34.6a	47.3a	17.8a	19.6a
0.17% Margosan-O	158a	142a	107a	15a	30.0a	41.9a	23.4a	13.7a
0.33% Margosan-O	125a	102a	106a	8a	32.1a	34.0a	22.5a	14.2a

Means within a column followed by the same letter are not significantly different at K-ratio = 100 ($P = 0.05$), Waller-Duncan K-ratio t-test.

* n = 4

** n = 5

Table 2. Mean pupae and mean pupal densities for various concentrations of Margosan-0 used against *L. trifolii* (Burgess) on floral crops.

Treatments	Mean Pupae				Mean Pupae/100 cm^2 leaf area			
	Chrysanthemum**	Marigold*	Zinnia*	Snapdragon*	Chrysanthemum**	Marigold*	Zinnia*	Snapdragon*
Control	119a	96a	102a	6a	21.2a	25.4a	23.0a	6.0a
0.0083% Margosan-0	84ab	107a	82a	5a	16.1ab	25.2a	21.2a	8.1a
0.083% Margosan-0	76ab	120a	69a	7a	16.0ab	31.9a	15.8a	5.0a
0.17% Margosan-0	45bc	104a	94a	4a	9.1bc	29.9a	21.0a	3.8a
0.33% Margosan-0	17c	67a	87a	3a	4.1c	22.8a	18.0a	3.5a

Means within a column followed by the same letter are not significantly different at K-ratio = 100 (P = 0.05), Waller-Duncan K-ratio t-test.

* n = 4

** n = 5

Table 3. Mean adult and mean adult densities for various concentrations of Margosan-O used against *L. trifolii* (Burgess) on floral crops.

	Mean Adults				Mean Adults/100 cm^2 leaf area			
Treatments	Chrysanthemum**	Marigold*	Zinnia*	Snapdragon*	Chrysanthemum**	Marigold*	Zinnia*	Snapdragon*
Control	57a	55ab	61a	2a	9.9a	14.4ab	13.9a	2.1a
0.0083% Margosan-O	41a	55ab	39a	2a	7.3b	12.9ab	10.3a	4.0a
0.083% Margosan-O	22b	60a	40a	3a	4.7c	16.0a	9.2a	2.1a
0.17% Margosan-O	3c	26bc	44a	2a	0.6d	7.8bc	10.0a	1.5a
0.33% Margosan-O	0c	5c	30a	1a	0d	1.5c	6.1a	1.0a

Means within a column followed by the same letter are not significantly different at K-ratio = 100 (P = 0.05), Waller-Duncan K-ratio t-test.

* n = 4

** n = 5

Table 4. Mean stipples and mean stipple densities for various concentrations of Margosan-O used against _L. trifolii_ (Burgess) on floral crops.

Treatments	Mean Stipples			Mean Stipples/100 cm^2 leaf area		
	Marigold	Zinnia	Snapdragon	Marigold	Zinnia	Snapdragon
Control	1714ab	451a	65a	462.8bc	111.6a	70.2a
0.0083% Margosan-O	1456b	562a	53a	349.7c	150.9a	79.8a
0.083% Margosan-O	2243ab	498a	104a	619.8ab	112.4a	87.5a
0.17% Margosan-O	2322a	442a	55a	674.6a	106.0a	51.5a
0.33% Margosan-O	1497ab	621a	73a	525.2abc	131.2a	81.2a

Means within a column followed by the same letter are not significantly different at K-ratio = 100 (P = 0.05), Waller-Duncan K-ratio t-test, n = 4.

Table 5. Comparisons of counts and densities of stipples, mines, pupae, and adults for water treated floral crops.

Floral	Mean				Mean Densities (per 100 cm^2 leaf area)			
Crops	Mines	Pupae	Adults	Stipples	Mines	Pupae	Adults	Stipples
Chrysanthemum**	210a	119a	57a	—	36.7a	21.1a	10.0a	—
Marigold*	126ab	96a	55a	1714a	33.0a	25.4a	14.5a	462.8a
Zinnia*	106b	102a	61a	451b	24.0ab	23.0a	13.9a	111.6b
Snapdragon*	12c	6b	2b	65c	10.7b	6.0b	2.1b	70.2b

Means within a column followed by the same letter are not significantly different at P = 0.05, Duncan's Multiple Range Test.

* n = 4

** n = 5

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Effects of Cyromazine (Trigard™) on *Liriomyza trifolii* (Burgess)

Gary L. Leibee[1]

Abstract

A bioassay procedure was developed to evaluate the dosage-mortality response of *Liriomyza trifolii* (Burgess) to cyromazine using infested cowpea, *Vigna sinensis*, plants. The LD_{50} and LD_{90} values for the larval stage were 6 ppm and 15 ppm, respectively. The number of deformed puparia developing from surviving larvae increased with dosage. A decrease in adult eclosion was associated with deformity of the puparia. Nine out of 14 generations of *L. trifolii* larvae were subjected to LD_{50} (6 ppm) pressure with cyromazine. LD_{50} and LD_{90} values indicated that no resistance had developed.

Introduction

Cyromazine, the active ingredient in Trigard™ (Ciba-Geigy), is a very effective development inhibitor against *Liriomyza trifolii* (Burgess). Cyromazine has had limited use on celery for leafminer control. Ciba-Geigy is pursuing full registration for the use of cyromazine on a variety of crops. Since *Liriomyza* leafminers have a history of developing resistance to insecticides (Leibee, 1981), it would be valuable to develop base-line data on the dosage-response relationship of *L. trifolii* to cyromazine to monitor populations for resistance after widespread use of cyromazine occurs.

This project was conducted to: (1) develop a relatively easy method of bioassaying insecticides against *L. trifolii* larvae, (2) generate base-line data for Trigard against *L. trifolii*, and (3) use these data and methods to attempt to select for cyromazine resistance in *L. trifolii*.

Methods and Materials

Dosage-Response. 'California blackeye' cowpeas, *Vigna sinensis*, were seeded in vegetable plug mix in bedding plant trays (Com-Packs, Model D812, T. O. Plastics, Inc.) and maintained at 25°C until the primary leaves were fully developed (approx. 7 days). These plants were placed into infestation cages containing newly emerged *L. trifolii* adults. The number of adults used varied due to availability. The plants were removed 24 to 48 hours later depending on the number of stipples present. A 48-hour maximum time of exposure to the adults was used to avoid hatching of the eggs before exposure to the insecticide.

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Solutions of cyromazine for dipping the plants were prepared from a 40 ppm stock solution of cyromazine made from 0.16 gram of Trigard 75 WP and 3000 ml of distilled water. The appropriate amounts of stock solution were diluted to 1800 ml to prepare 2, 4, 6, 8, 10, 12, and 14 ppm solutions of cyromazine. A wetting agent, 0.63 ml/l of X-77 (Chevron Chemical Co.), was added to the solutions to promote wetting of the cowpea leaves. A solution of distilled water and X-77 alone was used for the untreated check.

Each infested plant was removed from the plant tray, the leaves and part of the stem submersed for 5 seconds in the solution, and returned to the same plant tray. Ten plants were used for each dosage. The treated plants were maintained at 25°C until it was evident that larvae were about to exit the leaves. At this time, the leaves were excised and the leafmines counted. The leaves were then placed in plastic Petri dishes lined with filter paper and sealed with Parafilm(R) to prevent the leaves from drying out. After 7 days at 25°C, the pupae were retrieved and placed in plastic pill cups. The pupae were maintained at 25°C for 2 weeks to allow the adults to emerge and die. The puparia were examined and classified according to morphology as either normal, larviform, or otherwise abnormal. Adult emergence was recorded for each morphological type. Larval survival was calculated by dividing the total number of puparia (all morphological types) collected from a plant by the total number of leafmines it had contained. Abbott's formula was used to correct for mortality in the untreated check.

Resistance Study. Liriomyza trifolii adults reared from infested carrot foliage collected from a commercial vegetable farm in Zellwood, FL, were divided into two populations; one population to be selected at the LD_{50} level and the other population to serve as an unselected check. The selected population was exposed to cyromazine by placing the adults in an infestation cage containing cowpea plants that had been dipped in 6 ppm of cyromazine as described previously. Undipped plants were used in the infestation cage for the unselected populations. The plants were replaced every 2-4 days until there were very few stipples present on the leaves. After the last plants were removed, the cages were cleaned thoroughly to remove the flies. The plants were maintained as previously described. When the larvae were about to exit the leaves, the leaves were excised and placed onto 6.5 mm wire cloth in 22.9 X 31 X 10.5 cm deep, polystyrene boxes with lids (No. T295C, Tri-State Molded Plastics, Dixon, Kentucky). The bottoms of these boxes were lined with paper towels (No. 227, Veltex Singlefold Towels, Fort Howard Paper Co., Green Bay, Wisconsin) to absorb excess moisture to prevent the larvae from drowning. The pupae were retrieved from the boxes daily and placed into plastic pill cups. The pupae were stored at 10°C to arrest development until all the pupae from a generation were collected. All the pupae were then transferred to 25°C to allow development to the adult stage. All the adults were then introduced back into the infestation cage to repeat the procedure for the next generation. If the number of adults from a generation was low enough to endanger survival to the next generation, the selection process was skipped (leaves were not dipped in cyromazine) to remove deteterious effects of the cyromazine and allow the number of adults to increase to a level that insured survival to the next generation and still allowed selection.

Results and Discussion

Dosage-Response. Larval survival decreased with increasing cyromazine concentration as expected (Table 1). The LD_{50} and LD_{90} were 6 and 15 ppm, respectively. The dosage-mortality response occurred over a low and narrow range of concentrations (0-14 ppm) relative to the field rate of 300 ppm recommended for leafminer control on celery. This difference in the level of activity is not unexpected due to the inherent differences of these two systems, such as, plant species, application techniques, environmental conditions,and insect pressure.

The number of larviform and otherwise abnormally shaped puparia tended to increase with dosage (Table 2). There was a 5.8-fold increase in deformed (larviform + abnormal) puparia from 4 ppm to 6 ppm. Within each shape category there was no significant ($P > .05$) difference in adult eclosion due to dosage. A decrease in adult eclosion was associated with deformity. The mean percent adult eclosion $\pm$ SE over all dosages for each shape category was 93.5 ± 1.8, 13.3 ± 4.7, and 52.5 ± 5.2 for the normal, larviform, and abnormal puparia, respectively.

Resistance Study. Nine generations out of 14 were subjected to LD_{50} (6 ppm) pressure. F 3, 5, 6, 10, and 12 were not subjected to pressure because the number of adults from the preceding generation was considered too low to provide enough larvae to subject to pressure and still insure survival to the next generation. Examination of the LD_{50} and LD_{90} values for F1, 8, 9, 14, and 15 for the selected and unselected populations (Table 3) indicate that resistance had not developed.

Table 1. Dosage related survival of *L. trifolii* larvae in cowpea leaves dipped in cyromazine.

	ppm of cyromazine							
	0	2	4	6	8	10	12	14
% larval mortality	93.0 a[a]	91.0 a	71.0 b	57.5 bc	37.7 cd	33.0 d	11.5 e	9.0 e

[a]Means followed by the same letter are not significantly different ($P < 0.05$; Duncan's [1955] new multiple range test). ANOVA performed on transformed ($\sin^{-1}\sqrt{x}$) data.

Table 2. Percent composition of puparia shapes resulting from *L. trifolii* larvae exposed to different levels of cyromazine.

ppm of cyromazine	Normal	Larviform	Abnormal
0	98.6 a[a]	0.0 c	1.4 e
2	97.0 a	0.0 c	3.0 e
4	90.6 a	2.8 bc	6.5 de
6	50.0 b	21.5 ab	28.5 cd
8	29.4 bc	25.9 a	44.7 bc
10	12.7 c	23.2 ab	64.1 ab
12	21.6 c	16.1 abc	62.3 ab
14	14.4 c	7.9 abc	77.7 a

[a]Means followed by the same letter in each column are not significantly different ($P < 0.05$; Duncan's [1955] new multiple range test). ANOVA performed on transformed ($\sin^{-1}\sqrt{x}$) data.

Table 3. Responses to cyromazine of a population of *L. trifolii* subjected to LD_{50} pressure by cyromazine compared to an unselected population from the same parental stock.

Generation	Unselected		Selected	
	LD_{50} [a,b]	LD_{90} [a,b]	LD_{50} [a,b]	LD_{90} [a,b]
1	7.2	15.0	--	--
8	7.0	24.0	6.2	20.0
9	6.2	13.5	4.0	9.4
14	4.3	9.0	4.3	11.0
15	5.6	11.0	6.2	14.0

[a]ppm

[b]Values are estimates determined from line fitted by eye to data plotted on log-probit paper.

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Response of Liriomyza trifolii to Twospotted Spider Mites and Their Damage on Chrysanthemum

James F. Price and Cheryl Roesel[1]

Abstract. Twospotted spider mites (Tetranychus urticae ch) colonize and feed upon the lower surfaces of rysanthemum (Chrysanthemum X morifolium Ramat.) leaves. eir activity on upper surfaces of leaves is minimal except ter populations increase greatly. In contrast, adult riomyza trifolii (Burgess) leafminers feed and oviposit in per surfaces of chrysanthemum leaves and leafminer larvae velop there. Even though the two species largely occupy fferent leaf surfaces of the plant previous research data dicated that leafmining increased in chrysanthemum when ospotted spider mites were restricted to low densities by ticides. Those studies indicated that activities of afminer parasitoids were not reduced by the miticides and d no effect on the increased leafmining. This study was to termine if the twospotted spider mite or its effects on aves could result in reductions in leafminer eeding/oviposition punctures and mining in chrysanthemum.

In experiment 1, 5 treatments were applied to plots in 6 ndomized complete blocks. Treatments were 0, 5, 10, 15 or) adult, female, twospotted spider mites placed on the lower urface of each of 3 leaves on one 'Manatee Iceberg' rysanthemum plant. After 5 days of mite infestation the lants were put into a cage for 1 day to permit leafminer lies to feed and lay eggs. Five days later the numbers of eeding/oviposition punctures and mines were counted. In xperiment 2, four treatments in 12 randomized complete locks were included. Experimental units were 'Manatee ceberg' chrysanthemum plants with all but 2 leaves removed. ifteen adult, female, spider mites were placed on each of 2 eaves of plants in 2 of the treatments. Plants for the ther 2 treatments were not infested at that time. Four days ater leaves from one of the treatments infested were washed horoughly to remove mites and their eggs; 15 adult, female pider mites then were applied to 2 leaves of plants in one f the previously uninfested treatments. All plants ubsequently were exposed to adult leafminers for 1 day. esulting oviposition/feeding marks and leafmines were ounted 5 days later.

University of Florida, IFAS, Gulf Coast Research and ducation Center, Bradenton, FL, 34203 and New College, epartment of Natural Sciences, Sarasota, FL, 34243 espectively. Portions of this study were performed as an ndependent research project of the junior author.

In Experiment 1 numbers of feeding/oviposition marks and numbers of mines were greatly reduced when 5 mites were applied to leaves; further reductions in punctures and mines occurred from additional increments of mites. In Experiment 2, the highest numbers of punctures and leafmines occurred when no mites had been applied to the leaves or when mites were applied on the day chrysanthemums were introduced to adult flies. Large reductions in punctures and mines were evident when mites were allowed to develop on leaves for 5 days, both when mites were removed by washing or when they remained on the leaves.

These data support field observations that colonization of chrysanthemum leaves by twospotted spider mites reduces leafminer oviposition/feeding puncturing and subsequent mining. These data further indicate that these biological parameters are affected by leaf conditions caused by spider mites and not simply the presence of spider mites on the leaves.

The Comparative Responses of the Vegetable Leafminer, Liriomyza sativae (Blanchard) (Diptera: Agromyzidae) and the Greenhouse Whitefly, Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae), to Visual Stimuli.

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Abstract

The responses of the vegetable leafminer, Liriomyza sativae (Blanchard) (VLM), and the greenhouse whitefly, Trialeurodes vaporariorum (Westwood) (GHWF), to sticky yellow boards placed in various arrays in a greenhouse were compared in a series of 11 studies at Beltsville, MD and Baltimore, MD. Study 1 demonstrated, that for both L. sativae and a closely related serpentine leafminer, L. trifolii (Burgess), males and females were equally attracted to sticky yellow boards. Study 2 showed that there was a pronounced tendency for adult female L. trifolii to be caught on yellow sticky monitoring cards placed among a crop of chrysanthemums in a commercial greenhouse in Baltimore, MD. In Study 3, GHWF was influenced by board size by a factor greater than unity, while VLM landed in similar numbers on all boards, apparently ignoring board size. Study 4 demonstrated that proximity to the point-of-release was even more important than relative board size for GHWF. In contrast, VLM ignored both board size and distance from the release site in choosing a landing site. In Studies 5-10, GHWF preferred vertical to horizontal boards, while VLM generally preferred horizontal boards, apparently preferring a thin edge to a large area. Again, GHWF always preferred larger areas to smaller ones, and nearer objects to more distant ones, while VLM was unaffected by these parameters. VLM preferred to fly outwards rather than downwards from the point-of-release. GHWF always went preferentially to the object that would be perceived as larger when viewed from the point-of-release, and would readily fly downward if a lower board was perceived as being larger than an upper board. In Study 11, when boards were placed vertically or at 60° or 45° angles, at various heights, GHWF went preferentially to that board perceived as being larger from the perspective of the release point, while the VLM always preferred the 45° board to the 60° one, and the 60° board to the vertical,

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regardless of height of placement. In summary, GHWF responded very differently, often exactly the opposite, than did VLM to arrays of yellow sticky boards. The practical significance of these results is that, when attempting to improve catch of GHWF, both board area and proximity to the infestation should be maximized. When attempting to maximize catch of VLM, small yellow cards should be distributed at many locations throughout the greenhouse, or, thin sticky tapes should be strung down the middle of the greenhouse bench or bed, just above the level of the canopy.

Previous work at Beltsville, MD (Affeldt et al. 1983) determined the phototactic sensitivity level of the greenhouse whitefly (GHWF) (Trialeurodes vaporariorum (Westwood)) and the vegetable leafminer (VLM) (Liriomyza sativae (Blanchard)) to six series of color pigments. Results demonstrated that maximum response of both species occurred in the yellow-green region of 500- to 600-nm, and that capture of both species was inhibited by blue light energy from 400 to 490 nm. Generally, GHWF responded strongly to 5- to 10-nm shifts of spectra in the critical range of 510- to 540-nm, whereas VLM response to such shifts, while similar, was not strong enough to be statistically significant. The present study continues the analysis of the comparative visual behavior of these 2 species by comparing and contrasting their responses to yellow boards of varying size placed at varying distance from the point of release, and by varying the height of the boards and the position of the boards, as well as the angle of the boards, relative to the point of release. A second issue resolved is whether there are differences between sexes in the visual response of 2 leafminer species, L. sativae and L. trifolii (Burgess).

Methods and Materials

General Methods. All boards used in this study, unless otherwise specified, were made of Almac Yellow Plastic 2037 (Almac Plastics of Maryland, Inc., Baltimore, MD), the reflectance spectrum of which is given in Affeldt et al. (1983). This was the most attractive surface for both leafminers and whiteflies evaluated in that study. All boards were coated with Tack Trap[R] (Animal Repellents, Inc., Griffin, GA). The study was conducted in a 45-m^3 greenhouse, on the center bench of which 2 rings were established around a central release point (Fig. 1). The inner ring was 77-cm in diameter while the outer ring was 154-cm in diameter. Each ring was divided into 4 quadrants. The experimental design was a randomized block with 4 blocks with boards positioned in a repeated pattern in each block. The correct height, position, and angle of the boards was achieved either by suspending the boards from a plastic ring as per Affeldt et al. (1983), or by using ring stands. Adult whiteflies and adult leafminers were collected in the same glass vial by aspiration techniques, and this vial was placed into a 3.8-l widemouth glass bottle placed on a ring stand so that the top of the bottle, which was considered the actual release point, was 76-cm above the surface of

the bench (see Affeldt et al. 1983 for illustration). Thus the whiteflies and the leafminers were released simultaneously. The lid to the widemouth jar was suspended 8-cm directly above the top of the jar in order to orient them toward the trap array by preventing them from billowing straight upwards.

Studies 1 and 2. Sex-Ratio Studies. The studies reported here assume that male and female leafminer adults exhibit a similar response to visual stimuli. We tested this assumption in 2 ways. First, we released known numbers of each sex from our central release point. After 24-h we counted the numbers of each sex captured on a 30.6 x 30.6 x .3-cm board placed in each quadrant of the inner ring (at Position A in Fig. 1). We also mapped the position of each insect captured. In these trials, the release point was 60-cm above the bench while the top of the boards was 76-cm above the bench. There were 4 trials, 2 each for L. sativae and L. trifolii. Secondly, we evaluated the sex ratio found on sticky cards that had been placed at weekly intervals in a commercial chrysanthemum greenhouse to monitor L. trifolii populations. We evaluated 3 cards from each of 10 dates beginning March 8, 1984 and ending October 9, 1984. This permitted us to ascertain whether response to yellow boards varied in either sex by season. The monitoring cards used were 14.5 x 30.8-cm commercial sticky traps produced by Olson Products, Inc., Medina, OH.

Study 3. Comparative response of GHWF and VLM to Board Size. GHWF and VLM adults were released into an array consisting of 4 sizes of sticky panels, including 3 Almac boards 30.6 x 30.6 x 0.3-cm, 20.4 x 20.4 x 0.3-cm, and 10.2 x 10.2 x 0.3-cm, and an irregularly shaped commercial stake ("Sticky Bars," Reuter Laboratories, Inc., Haymarket, VA) circa 20 x 4 x 0.1-cm (73-cm^2 actual area). The yellow of the Reuter stake was virtually identical to that of the Almac boards. The boards were randomized for each quadrant of the outer circle, and placed at the 4 points C, D, E, and F in Fig. 1. The release point in this and all subsequent experiments was 76-cm above the bench. The experiment was run twice. Statistical analysis was done using the General Linear Models Procedure whereby linear regression for board size against % capture was computed for each species, and the significance of difference between the 2 regression coefficients was determined by means of the t-test. In this and all subsequent studies percentages were converted to angles using the arcsine transformation.

Study 4. Effect of Interceptor Board Size and Relative Distance from the Release Point on the Degree of Protection Provided for a Target Board against GHWF and VLM. In this experiment an "interceptor" board was placed (on Point A in Fig. 1) between the release point and a second, "target" board (placed on Point B in Fig. 1). The target board was always the 20.4 x 20.4-cm board used in the previous study, while the interceptor board was either the 10.2 x 10.2-cm (Case 3), the 20.4 x 20.4-cm (Case 1), or the 30.6 x 30.6-cm (Case 2) boards used in the previous study. Thus the interceptor board had either greater, equal, or less attractive surface than the target board. One such board-pair was placed in each quadrant for each trial, and there were 2 trials for each type of pairing. GHWF and VLM adults were

imultaneously released into the center of the array for each trial as n the previous experiment, and we recorded their subsequent capture n the board 24-h after release. After weighting our data to liminate directional effects, we compared our observed data for each ndividual species, using the Chi-Square Test, against theoretical alues based on the following assumptions: A) That size and distance ad no effect on capture; that is, there should be a 50:50 istribution on the boards on the inner and outer ring. B) That elative board catch is proportional to board size; therefore,

$$\text{\% Capture on Inner Board} = \frac{xi}{xo} \Big/ \frac{xi}{xo} + 1 \qquad \text{(Formula 1),}$$

nd

$$\text{\%Capture on Outer Board} = 1 \Big/ \frac{xo}{xo} + 1 \qquad \text{(Formula 2),}$$

here xi = area of the inner board and xo = area of the outer board.

) That relative board catch is based on relative distance from the eleaae point; therefore,

$$\text{\% Capture on Inner Board} = \frac{do}{di} \Big/ \frac{do}{di} + 1 \qquad \text{(Formula 3)}$$

ıd

$$\text{\% Capture on Outer Board} = 1 \Big/ \frac{do}{di} + 1 \qquad \text{(Formula 4),}$$

ıere do = distance of the outer board, and di = distance of the inner ›ard, from the release point.

That relative board catch is equally influenced by board size and ·lative distance from release point; therefore,

$$\text{\% Capture on Inner Board} = \left(\frac{xi}{xo}\right) \cdot \left(\frac{do}{di}\right) \Big/ \left(\frac{xi}{xo}\right) \cdot \left(\frac{do}{di}\right) + 1 \qquad \text{(Formula 5),}$$

d

$$\text{\% Capture on Outer Board} = 1 \Big/ \left(\frac{xi}{xo}\right) \cdot \left(\frac{do}{di}\right) + 1 \qquad \text{(Formula 6),}$$

ere xi, xo, di, and do are as above.

The same as Assumption D, but the effect of distance is squared; erefore,

$$\text{\% Capture on Inner Board} = \left(\frac{xi}{xo}\right) \cdot \left(\frac{do}{di}\right)^b \Big/ \left(\frac{xi}{xo}\right) \cdot \left(\frac{do}{di}\right)^b \qquad \text{(Formula 7),}$$

ı

$$\text{\% Capture in Outer Board} = 1 \left(\frac{xi}{xo}\right) \cdot \left(\frac{do}{di}\right)^b + 1 \qquad \text{(Formula 8),}$$

ɜre xi, xo, di, do are as above, and b = 2.

the fourth power; therefore,

Formula 9 is the same as Formula 7,

and

Formula 10 is the same as Formula 8, except that b = 4.

G) This assumption is the same as assumption F except that it provides a modest increase in the importance of relative board area by raising relative area by a power of 1.4; therefore:

$$\% \text{ Capture of Inner Board} = \left(\frac{xi}{xo}\right)^a \cdot \left(\frac{do}{di}\right)^b \Big/ \left(\frac{xi}{xo}\right)^a \cdot \left(\frac{do}{di}\right)^b + 1 \quad \text{(Formula 11)},$$

and

$$\% \text{ Capture of Outer Board} = 1 \Big/ \left(\frac{xi}{xo}\right)^a \cdot \left(\frac{do}{di}\right)^b + 1 \quad \text{(Formula 12)},$$

where xi, xo, di, do are as above, a = 1.4 and b = 4.

Studies 5-8. Effect of Vertical versus Horizontal Placement. We conducted a series of 4 experiments (Studies 5-8) comparing horizontal versus vertical placement of target boards. In study 5, the boards were placed either horizontal or vertical to the point of release, and were alternated along the inner circle (Points A and G in Fig. 1). The horizontal board was placed level with the bottom edge of the vertical board; that is, 56-cm from the surface of the bench. Study 6 was similar to Study 5, except that a second vertical board was hung at the same height as the first on the outer circle (at Point H in Fig. 1). Study 7 was the same as Study 5 except that the vertical board was moved from the inner circle to the outer circle (to Point B in Fig. 1), with the horizontal board left at Point G. Study 8 was similar to the other 3 studies in this series except that a vertical board was suspended at Point A 76-cm above bench level, a horizontal board was placed at Point A 15-cm above bench level, and a horizontal board was placed at Point B on the outer circle, also 15-cm above bench level.

All target boards used in these 4 studies were the 20.4 x 20.4-cm boards used in Studies 3 and 4, and adult GHWF and VLM were released as above. There were 2 trials for each study. Each array was repeated in each quadrant for each trial in each study.

We initially ran a 2-way ANOVA for all 3 studies with "species" as one factor and "position" as a second factor. However, for all 3 studies we obtained a significant species x position interaction. Therefore, for each study, we ran a 1-way ANOVA for each species to determine the significance of position, and paired t-tests to compared the 2 species at each position.

Study 9. Horizontal Boards Placed at 3 Heights. Three 20.4 x 20.4 x .3-cm Almac Plastic 2037 yellow boards were placed horizontal to the release point on a pole, one above the other, at 3 heights: 25-, 51-, and 76-cm. One such pole was placed (at Point B on the outer circle in Fig. 1) in each of the 4 quadrants. As in the preceding studies,

adult GHWF and VLM were simultaneously released from a central release point that was 76-cm above the bench. There were 2 trials, so results are based on counts of 8 boards at each height. To determine whether the distribution of capture of the 2 species on the boards were different, statistical analysis was done using the General Linear Regression Models Procedure where by linear regression for board height against % capture was computed for each species, and the significance of difference between the 2 regression coefficients was determined by means of the t-test.

Study 10. Boards Placed at 45° Angle to the Release Point, at 3 Heights. Study 10 was identical to Study 9 except that the horizontal boards of Study 9 were rotated 45° with respect to the release point.

Study 11. The Effect of Board Angle on the Capture of adult GHWF and VLM, at 3 Heights. Study 11 was a set of 3 experiments in which 20.4 x 20.4 x .3-cm Almac Plastic 2037 yellow boards were placed on poles at 3 angles relative to the release point: 90°, 60°, and 45°. One board was placed per pole. The boards were randomized for each quadrant of the outer circle, and placed at the 3 points H, I, and J in Fig. 1. The first experiment in Study 11 was done with the center (pivot line) of the boards at 76-cm. In the second experiment the boards were placed at 51-cm, and in the third experiment, the boards were placed at 25-cm. As in the preceding studies, adult GHWF and VLM were simultaneously released from a central release point that was 76-cm above the bench. There were 8 trials at the 76-cm height, and 4 trials at the 51-and 25-cm heights, so that results represent totals for 32, 16, and 16 boards for each angle at the respective heights.

Each experiment was statistically analyzed using the General Linear Regression Model whereby linear regression for board angle against % capture was computed for each species, and the significance of difference between the 2 regression coefficients was determined by means of the t-test.

Results

Sex Ratio Study 1. As seen in Table 1, most adult leafminers of both sexes for both species were caught within 24-h of release. There was no sign of a sex bias for capture for either species.

Sex Ratio Study 2. As seen in Table 2, there was no consistent trend for a sexual bias in the numbers of adult L. trifolii caught on monitoring yellow cards taken from a natural population infesting a commercial chrysanthemum greenhouse near Baltimore, Maryland. Although more females than males were trapped on most dates, we feel that this may well reflect actual population trends in the greenhouse. Significantly more females than males were caught during 4 of 10 trapping periods.

Study 3. Comparative Response of GHWF and VLM to Board Size. As seen in Fig. 2, GHWF adults responded to the largest board more strongly than would be expected based on its relative area in the array. GHWF showed decreasing response to board size as board size decreased. Conversely, VLM adults responded less than expected to large boards and more than expected to small boards. Linear regression of board size against % capture yielded a regression equation of $y = -18.5x + 72.0$ with a regression coefficient of 3.6 for GHWF, and $y = -3.2x + 37.8$ with a regression coefficient of 1.1 for VLM. These regression coefficients were significantly different at the 1% level using the t-test, indicating a significant difference in response of the 2 species to board size.

Study 4. Effect of Relative Board Size and Relative Distance from Release Point on the Degree of Protection Provided for a Target Board against GHWF and VLM. Results of Study 4 are given in Fig. 3. Adult VLM's distributed themselves in a much different pattern than did GHWF adults. Percent VLM adults landing on inner versus outer boards were 51:49; 51:49, and 54:46, respectively, for Cases 1, 2, and 3. In all 3 cases, these results were not significantly different by Chi-Square Analysis from the 50:50 results expected from Assumption A. Thus, VLM adults seemingly ignored both board size and relative distance from release point under the conditions of this study. On the other hand, observed catch of adult GHWF on inner versus outer boards was 94:6, 98:2, and 69:31 for Cases 1, 2, and 3, respectively. Obviously, both board size and distance from release point affected % board catch of GHWF. The relative importance of these 2 factors can be deduced by comparing the observed pattern of capture with expected captures based on Assumptions B-G. Assumption B was that relative board size was the only important factor. Using Formulas 1 and 2, this assumption predicted inner:outer board catches of 50:50, 69:31, and 20:80 for Cases 1, 2, and 3, respectively. Clearly, Assumption B was wrong. Assumption C was that expected board catch was proportional to the distance from the release point. Since board size was ignored and the relative distance from the release point was 2 for all 3 Cases used in this study, the expected ratios, based on Formulas 3 and 4, would always be 67:33. While this was closer to observed values than Assumption B, and was a plausible fit for Case 3, Assumption C was obviously not the entire story. Assumption D was that relative board catch was equally influenced by board size and relative distance from the release point. Expected ratios calculated from Formulas 5 and 6 were 67:33, 82:18, and 33:67 for Cases 1-3, respectively. Again, Assumption D did not agree with observed results. Assumption E was the same as Assumption D, except that the role of distance was emphasized by squaring this factor. Using Formulas 7 and 8, ratios of 80:20, 90:10, and 50:50 were calculated for Cases 1-3, respectively. While still fairly distant from observed results, Assumption E seemed to be heading in the right direction. Assumption F increased the role of distance still more by raising this factor to the fourth power. Using Formulas 9 and 10, we calculated ratios of 94:6, 97:3, and 80:20 for Cases 1-3, respectively. While quite close to observed values, we

felt we needed to increase the influence of board size, especially since Study 3 had demonstrated that the influence of board size was greater than unity. We found that modifying Assumption F by raising the influence of area to the 1.4 power (Assumption G) resulted, using Formulas 11 and 12, in calculated ratios of 94:6, 98:2, and 70:30. This was similar to observed values in all 3 cases, and for the first 2 cases, were statistically in agreement by Chi-Square Analysis.

Studies 5-8. Effect of Vertical versus Horizontal Placement. Results of Study 5 are given in Fig. 4 A. Distribution of GHWF adults on the horizontal versus the vertical boards were 95:5 in favor of the vertical. On the other hand, VLM adults distributed themselves 59:41 in favor of the horizontal. Results of a 2-way ANOVA test for GHWF versus VLM as one factor and horizontal versus vertical placement as a second factor gave a highly significant interaction for insect x position, indicating that GHWF adults responded to the board array differently than did the VLM. When 1-way ANOVA's were run independently for GHWF and for VLM, the GHWF preference for the vertical was significant at the 1% level while the VLM preference for the horizontal was significant at the 5% level. Paired t-tests run independently for the vertical and for the horizontal board positions showed that the means of the GHWF and the VLM were significantly different at the 1% level for both board positions, another indication that the 2 species responded differently to the array.

Results of Study 6 are given in Fig. 4 B. Percentages of GHWF adults landing on the 3 board positions (inner horizontal: inner vertical: outer vertical) were 1:96:3, while results for VLM results were 45:30:25. Again, GHWF showed a strong preference for the vertical board over the horizontal, and the inner vertical board over the outer vertical board, and again, VLM showed a preference for the horizontal board over the vertical board, but little preference for the inner vertical board over the outer vertical board. Results of a 2-way ANOVA test for GHWF versus VLM as one factor and the 3 board placement positions as the second factor gave a highly significant interaction for insect x position, once again indicating that GHWF adults responded to the board array differently than did the VLM adults. When 1-way ANOVA's were run independently for GHWF and for VLM, positional effects were significant at the 1% level for GHWF and at the 5% level for VLM. Paired t-tests run independently for all 3 board positionings showed that capture means of the GHWF and the VLM were different at the 1% level for all 3 positionings, again indicating that the 2 species responded differently to this array.

Results of Study 7 are given in Fig. 4 C. Distribution of GHWF adults on the inner horizontal boards compared to the outer vertical boards were 87:13 in favor of the inner horizontal position. The VLM adults also favored the inner horizontal boards, but by a less pronounced ratio of 58:42. However, 2-way ANOVA still gave a significant insect x position interaction, indicating that the 2 species did not respond to the array exactly the same way. When 1-way ANOVA's were run independently for GHWF and VLM, positional effects were significant at the 1% level for GHWF but non-significant for

VLM. Paired t-tests run independently for both positionings were non-significant for % species captured for either board positioning.

Results for Study 8 are given in Fig. 4 D. Percentages of GHWF adults landing on the 3 board positions (inner vertical-high, inner horizontal-low, outer horizontal-low) were 79:18:3 for GHWF and 65:15:20 for VLM. Although the response to this array was very similar for the 2 species, enough difference occurred to result in a significant species x position interaction in the 2-way ANOVA test. When 1-way ANOVA's were run independently for GHWF and for VLM, positional effects were significant for both species. Paired t-tests comparing % capture for the 2 species were run independently for each of the 3 board positionings. Significant differences in catch was seen for the inner vertical (5% level) and the outer horizontal (1% level) positionings, but not for the inner horizontal positioning.

Study 9. Horizontal Boards Placed, at 3 Heights. Results for Study 9 are seen in Fig. 5. The 2 species responded in almost the exact opposite manner to this array. The ratio of GHWF capture was 9:33:58 for the 76-cm, 51-cm, and 25-cm boards, respectively, while the ratio of VLM capture was 59:32:9. Linear regression of board height against % capture yielded a regression equation of $y = 16.7x + .5$ with a regression coefficient of 2.9 for GHWF, and $y = -17.0x + 67.7$ with a regression coefficient of 2.0 for VLM. These regression coefficients are significantly different at the 1% level using the t-test, indicating a significant difference in response of the 2 species to this array.

Study 10. Boards Placed at a 45° Angle to the Release Point at 3 Heights. Results for Study 10 are given in Fig. 6. The ratio of GHWF capture was 45:21:34 for the 76-cm, 51-cm, and 25-cm boards, respectively, while the ratio of VLM capture was 55:29:17. Linear regression of board height against % capture yielded a regression equation of $y = -3.5x + 41.9$ with a regression coefficient of 3.5 for GHWF and a regression equation of $y = 17.6x + 59.8$ with a regression coefficient of 2.5 for VLM. These regression coefficients were not significant at the 5% level using the t-test, indicating that response of the 2 species to this array was similar.

Study 11. Effect of Board Angle, at 3 Heights. Results for Study 11 are given in Fig. 7. At the 76-cm height, the ratio of GHWF capture was 42:35:23 for the 90°, 60°, and 45° boards, respectively, while the ratio of VLM capture was 26:35:38. Linear regression of board angle against % capture yielded a regression equation of $y = 6.8x + 21.1$ with a regression coefficient of 2.1 for GHWF and a regression equation of $y = -3.7x + 42.4$ with a regression coefficient of 1.1 for VLM. These regression coefficients were significantly different at the 1% level using the t-test, indicating a significant difference in response of the 2 species to board angle at the 76-cm height.

At the 51-cm height, the ratio of GHWF capture was 35:33:32 for the 90°, 60°, and 45° boards, respectively, while the ratio of VLM capture was 21:33:46. Linear regression of board angle against % capture yielded a regression equation of $y = -.1x + 35.3$ with a regression coefficient of 1.9 for GHWF and a regression equation of $y = -8.2x + 51.3$ with a regression coefficient of 1.4 for VLM. Again, these regression coefficients were significantly different at the 1% level using the t-test, indicating a significant difference in response of the 2 species to board angle at the 51-cm height.

At the 25-cm height, the ratio of GHWF capture was 35:33:32 for the 90°, 60°, and 45° boards, respectively, while the ratio of VLM capture was 17:33:49. Linear regression of board angle against % capture yielded a regression equation of $y = 1.0x + 33.2$ with a regression coefficient of 1.3 for GHWF, and a regression equation of $y = -10.2x + 55.2$ with a regression coefficient of 1.0 for VLM. Once again, these regression coefficients were significantly different at the 1% level using the t-test, indicating a significant difference in response of the 2 species to board angle at the 25-cm level.

Discussion

Working in fields of tomato and celery in California, Zehnder and Trumble (1984) reported that a greater proportion of male L. trifolii and L. sativae were caught on sticky yellow traps in their studies than females, while pupae reared from foliage indicated that such catches should have been equal. They suggested that the skewed sex ratios might be explained in behavioral terms; that is, the females might spend more time on the leaves during oviposition or the males might visit a greater number of leaves in search of food and females. These findings might suggest that sticky yellow cards would be of little use in the direct control of leafminers if females tended to avoid such traps. Conditions in both Study 1 and Study 2 of the present paper were far different from those of Zehnder and Trumble, so direct comparisons are not warranted. However, Study 1 did indicate that skewed sex ratios would not be expected in Studies 3-11 of this paper, especially because there was no plant foliage in these studies to distract either the males or the females. Study 2, conducted with chrysanthemums under greenhouse conditions in Baltimore, MD, was not accompanied by the rearing of individuals from the host foliage to determine the expected sex ratios. Thus we cannot determine whether the greater percentage of females than males caught in this study reflected a behavioral bias or merely reflected an actual skewed sex ratio in this population. However, we can conclude that L. trifolii females were attracted to and caught on yellow sticky cards in large numbers, and under certain circumstances may be useful in leafminer population suppression. Indeed, Herbert et al. (1984) concluded from tests in commercial greenhouses that growers might be expected to reduce foliar damage to chrysanthemum crops caused by L. trifolii by half by hanging sticky yellow boards at 1.5-m spacings. The question of skewed sex ratios in leafminer populations is an interesting one, and deserves further study.

Studies 3-11 compared and contrasted adult GHWF responses with those of VLM adults to arrays of sticky yellow boards. Generally, GHWF responses were very different, often exactly the opposite, to those of the VLM. As seen in Study 3, GHWF was influenced by board size by a factor greater than unity. That is, more GHWF landed per unit area on the larger boards than the smaller ones. Just the opposite was seen with VLM, with similar numbers of leafminers landing on all boards, apparently ignoring board size. Although Study 4 confirmed that GHWF was influenced by board size to a degree greater than unity, it also demonstrated that distance from the release point was a far more important factor than mere board size for GHWF. On the other hand, VLM was as little affected by distance from release point as it was by board size--it seemingly ignored both. In Study 5, GHWF greatly preferred the vertical boards to the horizontal ones. This agrees with results from Studies 3 and 4, since, when viewing the boards from the release point, the horizontal board would be perceived as a thin edge, while the vertical board would appear far larger. On the other hand, VLM apparently preferred the 'thin edge.' Herbert et al. (1984) compared horizontal boards to vertical boards for trapping L. trifolii, with mixed results. However, because their boards were positioned with bottoms 15-cm above the canopy, the boards would appear somewhat different to flies at canopy level than our array would appear at our release point. Therefore, results of the 2 studies are not strictly comparable.

Results for Study 6 for GHWF capture was virtually identical to results for Study 4, with GHWF choosing the larger, closer silhouette (inner vertical board), while VLM showed a slight preference for the inner horizontal over the outer vertical board, but no preference for the inner vertical over the outer vertical board.

Results for Study 7 again demonstrated that GHWF preferred a closer object that would have been perceived as smaller at the release point over a more distant, larger silhouette. The VLM also preferred the inner horizontal board to the outer vertical one, although to a much less degree than seen for GHWF. This was the first array that yielded similar capture trends for the 2 species. However, since 2-way ANOVA still gave a significant insect x position interaction, it is apparent that the 2 species did not respond to the array in exactly the same way.

Results for Study 8 showed that GHWF preferred the inner vertical board at 76-cm over the inner horizontal board at 15-cm by a ratio of 79:18. This is less pronounced than the 95:5 ratio seen for vertical vs horizontal boards placed at the same height in Study 5. This was because, seen from the point-of-release, the lower horizontal board would not appear as a thin edge, but would appear larger than the same board placed at 76-cm. This also probably explains why VLM preferred the higher vertical board to the horizontal boards placed at 15-cm, unlike results seen in Study 5. Apparently both GHWF and VLM prefer to fly outward rather than downward from the point-of-release.

Results in Study 9 were fully consistent, for both pest species, with the previous results seen in Studies 3-8. As seen from the point-of-release, the topmost horizontal board would appear to be a thin edge, while the middle and bottom boards would appear progressively larger. Thus more whiteflies flew to the apparently larger silhouette (bottom board) than to the apparently smaller middle board or to the 'thin edge' (top board). Conversely, VLM went preferentially to the 'thin edge' (top board) and progressively less to the 2 lower boards.

When the horizontal boards of Study 9 were rotated by 45° (Study 10), their perception at the point-of-release was radically altered. The bottom board would still seem somewhat larger than the other 2 boards, and thus it attracted its share of GHWF. However, the upper board would now be much more apparent, and being the closest board to the release point, was the most favored. The VLM once again seemed to prefer to fly outward to the top board than downward to the 2 lower boards.

In Study 11, the vertical boards at the 76-cm level would be more prominent to an observer at the point-of-release than the boards placed at 60°, which in turn would be more prominent than the boards placed at 45°. This explained the GHWF preference for 90° over 60° over 45°. As the boards were placed at increasingly lower levels, all boards would tend to be equally prominent, and thus GHWF went to all boards equally when they were placed at 51-cm or 25-cm. On the other hand, VLM preferred the 45° boards over the 60° boards, and the 60° boards over the vertical boards, when the boards were placed at 76-cm. This preference successively increased as the boards were lowered, first to the 51-cm height, and then to the 25-cm height. The reason for this preference was not clear, and might form the basis for future studies.

All of the above has obvious practical significance. When attempting to catch GHWF, both board area and proximity to the infestation should be maximized. Other parameters important for using sticky yellow boards effectively against GHWF are discussed elsewhere (Webb et al. 1985). For maximum effectiveness, the boards should be combined with the use of the parasitoid *Encarsia formosa* Gahan (Webb and Smith 1980). When attempting to catch VLM, board area and proximity to the infestation are less important. Thus, the best strategy for capturing VLM is either to distribute small sticky yellow cards at many points throughout a greenhouse, or to string thin yellow sticky tapes just above the crop canopy down the middle of the greenhouse bed or bench. Placing the card or tape at an angle may elp, but this needs more clarification. In all cases, the small rds or tapes should be placed just above the crop canopy.

Acknowledgements

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Table 1. Release and subsequent recapture after 24-h of adult males and females of 2 leafminer species. Results of 2 trials for each species.

	Males		Females	
Trial	No. Released	No. Recaptured	No. Released	No. Recaptured
		Liriomyza sativae		
1	52	52	45	43
2	20	19	24	20
		L. trifolii		
1	21	19	25	15
2	24	17	24	17

Table 2. Sex ratio of *Liriomyza trifolii* adults trapped on yellow sticky cards in a commercial chrysanthemum greenhouse by dates. Average percentage of 3 boards counted per date.

Date	Total adults counted	% Female
3/8-3/13/84	816	55± 24.8
3/13-3/20	631	69± 16.5*
3/20-3/27	1473	49± 8.6
3/27-4/3	2931	60± 28.6
4/3-4/10	2726	67± 20.7
5/1-5/8	1611	53± 6.0
6/5-6/12	617	67± 10.8*
7/3-7/10	611	70± 6.5*
8/7-8/14	3455	61± 4.9*
10/2-10/9/84	376	62± 15.0

* The confidence intervals indicate that significantly more females than males caught on these dates.

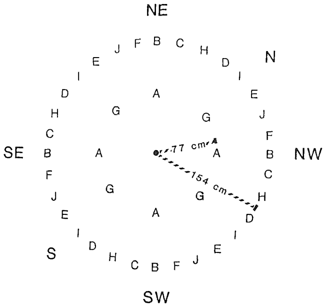


Figure 1. Diagram of experimental rings, with the position of boards on the rings designated by the appropriate letters.

Board Size:	30.6 x 30.6	20.4 x 20.4	10.2 x 10.2	73 cm^2
Expected:	61.2%	27.2%	6.8%	4.8%
Observed:				
Whitefly:	81.1%	14.5%	2.9%	1.4%
Leafminer:	33.1%	22.7%	28.9%	15.4%

Figure 2. Effect of board size on % capture of greenhouse whitefly and vegetable leafminer adults.

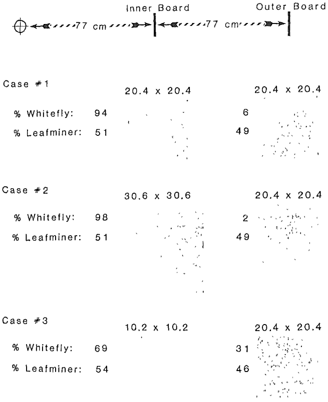


Figure 3. Effect of board size, and distance from the point-of-release, on % capture of greenhouse whitefly and vegetable leafminer adults.

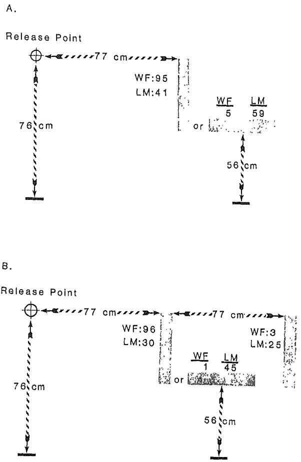
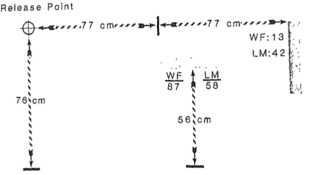


Figure 4. Effects of vertical versus horizontal placement on % capture of greenhouse whitefly (WF) and vegetable leafminer adults (LM).

A. Results of horizontal boards (56-cm) vs. vertical boards (76-cm) placed alternately on the inner ring.

B. As in 4A, plus an additional vertical (76-cm) board on the outer ring.

C.



D.

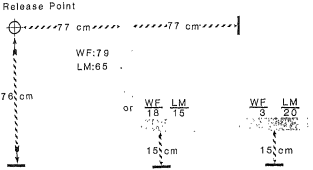


Figure 4C. As for 4B, except the vertical (76-cm) board on the inner ring was removed.

D. Results of vertical (76-cm) vs. a horizontal board (15-cm), both on the inner ring, vs. a horizontal board (15-cm) on the outer ring.

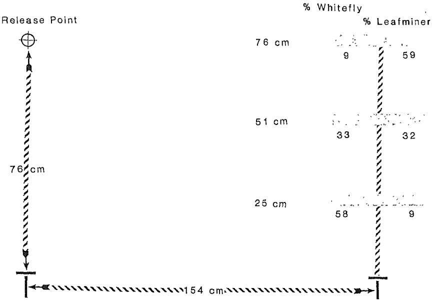


Figure 5. Effect of horizontal boards placed at 3 heights (25cm,51cm,76cm) on % capture of greenhouse whitefly and vegetable leafminer adults.

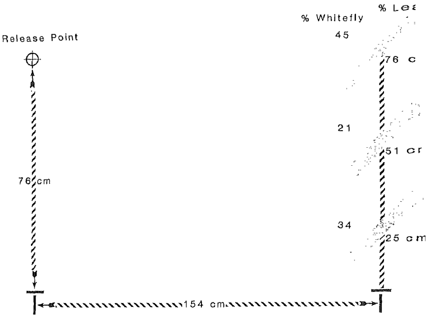
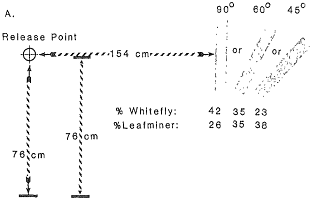


Figure 6. Effect of boards placed at a 45° angle to the release point, at 3 h (25cm,51cm,76cm), on % capture of greenhouse whitefly and vegetable miner adults.



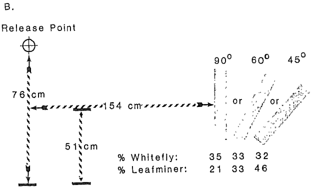


Figure 7. Effect of board angle, at 3 heights, on % capture of greenhouse whitefly and vegetable leafminer adults.
A. Boards placed at 76-cm.
B. Boards placed at 51-cm.

C.

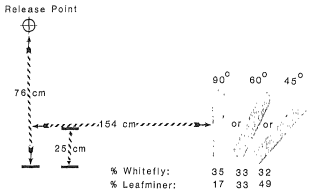


Figure 7C. Boards placed at 25-cm.

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Liriomyza leaf miners: Potential for Management - A Summary

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Space in the Entomological Society of America Program for an Informal Conference on *Liriomyza* in 1984 is welcome, though not unusual. During the past few years many state, branch, national and even international conferences have found time and space for scientists to discuss leaf miners. In 1981, 1982, 1983 and 1984 special meetings have been called by leaders of industry and the land grant colleges to address the concerns raised by the tiny leaf mining flies. Nor is it unusual to have a proceedings of the conference produced. These have been compiled and issued for 1981 (Proceedings of the IFAS-Industry Conference on Biology and Control of *Liriomyza* leafminers); 1982 (Proceedings of the 3rd Annual Industry Conference on the Leaf miner, San Diego, CA); and 1984 (Proceedings of the 4th Annual Conference on the leaf miner, Sarasota, FL). In addition International conferences in Britain and in Hamburg, Germany have carried symposia and special sessions on the biology and management of *Liriomyza*.

The current meeting represents a continued effort to promote the excellent communication established among scientists and industry on this problem. The threat of leaf miners has welded industry leaders, researchers, and producers together with speed and in a manner that is nothing short of remarkable. Other crop industries threatened by other species of pests have used the leaf miner as a model for University-Industry cooperation. That is a major achievement in itself.

Relative to the miner question, what possible new information can be garnered from this meeting, especially when its participants have contributed repeatedly to other conferences, even during the current year? For one thing, audiences vary from place to place, but at the ESA meeting entomologists address other entomologists. Consequently, it provides a forum for critical feedback from colleagues about the intrinsic worth and potential value of research data obtained in different situations. For another thing, such a forum can be used to update and report the progress of research and compare notes on the cyclical population phenomena around the country.

Physiological Plant Response

The emphasis on damage, particularly physiological plant response to leaf miners, is welcome research since it clearly demonstrates what growers have attested for years: a high degree of plant part variability irrespective of insect attack. It is interesting to note that even a single leaf miner significantly reduced celery viability, and that a dozen punctures per leaf were sufficient to indicate a significance in variation. The common assumption that impairment of plant response, i.e. reduced stomatal and mesophyll conductance, transpiration and photosynthesis, at any level is economically detrimental needs clarification.

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The contrast in control and parasitism between methomyl and methamidophos is useful in cases where biological mortality is substantial and should be sustained.

Biological Control Tactics

Species of parasites respond differently to chemical pesticides, much as does the leaf miner. Organophosphates generally depress parasite emergence. This was found to be true for Diglyphus, but OP's seemed to favor Chrysonotomyia. Just the opposite was true for the pyrethroid Ambush®. However, relative toxicity of pesticides to both parasite and host, with concomitant and changing levels of host availability is a tangle for future students to unravel.

Basic study of parasite biology continues to yield information that can be translated into a management strategy. High temperatures of ($> 23.3°C$) retarded D. intermedius oviposition on tomatoes, increased mortality and resulted in fewer larvae killed per parasite. Host feeding by this parasite yielded a substantial mortality apart from oviposition.

That species of Liriomyza as well as their parasites vary with the season has been reaffirmed. Results from a four year survey reveal that in Florida the predominant pest leaf miner species shifted from L. sativae in 1980 to L. trifolii in 1984. These data confirm what was surmised to have occurred in the agricultural semi-tropics when new practices or chemical products are introduced.

A practical IPM program for leaf miner and other pests of glass houses appears to be much closer for Ohio vegetables than for California chrysanthemums. Parasites released onto populations of leaf miners in Ohio tomatoes suppressed miner populations to a level where impact on yield weight was not significant. Biological control by parasite releases in California was considered a failure due to excessive temperatures.

The success of biological/chemical integrated programs is now a matter of releasing the best adapted species of parasite into a host level at a time when the population can be curbed before damage results. Such a managed program is sure to be possible as we learn to manipulate these variables confidently in a more systematic fashion.

Chemical Control Tactics

An exciting botanical extract of the neem seed has been the subject of intense study by the USDA. Margosan-O, used as a pot drench, demonstrates a varied efficacy with host plant species. Generally, the toxicant reduced larval and pupal development and the emergence of adults. Life cycle disruption was noted when drenches were applied to beds of floral plants.

Interspecific Competition

Research into the interactions of two widely different pest species that attack a common host at the same time provides basic insight into pest management. The presence of one species tended to suppress the

population level of the other, i.e. large numbers of spider mites suppressed levels of leaf miners. Favorable mite control (with acaricides) increased the need to control leaf miners. Miticides had little effect on parasite activity. The implications of these population phenomena may in some way be related to the physiological response of celery to physical damage noted in an earlier paper.

Visual Response to Sticky Cards

Studies over several years on the response of *Liriomyza* to visual stimuli (yellow card) suggest that sex differences do not exist even though larger numbers of females may be trapped on yellow cards in chrysanthemums. Likewise, size of the trap and distance from release point was not significant for the flies, although yellow traps placed at a 45° angle was preferred over 60° angle and vertical. Practical use of these responses is given in the advice to distribute a large number of small yellow cards at many sites throughout the greenhouse.

Conclusions

From the discussions at this conference it is evident that entomologists know much about *Liriomyza* spp. that was not known a few years ago. We can sample the adults, larvae and pupae and do so routinely, in many different ways. We can count punctures, mines, measure plant height, weight and physiological responses to the leaf miner. We have developed, screened, and evaluated a range of chemical toxicants and can predict mortality under different use patterns. We have recruited natural enemy parasites from different areas of the world to help us in our battle to control the pest. We have subjected them (the parasites) to the unnatural environmental conditions of greenhouse, saranhouse and laboratory chamber and to the added stress of high or low pest density and an assortment of chemical fixes.

We have, in short, generated reams of research data about the pest. But, what have we done to manage the pest? Improved sanitation, i.e. a clean plant to begin with, has a season-long advantage. A few products (e.g. Trigard) reduces numbers substantially while nurture of parasites provides additional mortality. Timing applications for larval control has its advantages. In spite of all this, many growers still experience unaccountably large and damaging populations. Why?

The thesis of differing susceptibility to insecticides could be tested by alternation of product or by judicious use of tank mixes on a large scale. Host plant resistance, biological control and plant growth regulators, all proven in experiments to be useful for control have yet to be integrated into a truly long term managed program. I believe that soon soil, plant, cultural, environment, chemicals and biological variables will be included in a strategy to bring leaf miner control in as an integral part of crop management. Combining entomological knowledge with that of other crop disciplines and specialists: plant pathologists, weed scientists, horticulturists, and others will undoubtedly provide the broad framework in which our theories are real-world tested. We can then assess our progress on a par with the producer.